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Effect of Selenium and Silicon Foliar Applications on the Growth and Yield of Common Bean

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RECENTLY, the importance of the beneficial elements for humans, animals, and plants has been clarified. Element fortification in plants is an excellent strategy for suppling elements through the food chain. The beneficial elements could promote growth in plants which comprise selenium, silicon, cobalt, and sodium. Nowadays, evaluating the impact of beneficial elements such as selenium and silicon on the growth and productivity of various plant species has become a novel approach. Therefore, field experiment was conducted to evaluate the effect of foliar application of selenium in form of sodium selenite at levels of 10, 20 and 30 µmol, and silicon in form of sodium silicate at levels of 0.5, 1 and 2 mM plus water served as control treatment on vegetative growth, SPAD reading, mineral contents in leaves and seeds, and seed yield and quality of common bean (*Phaseolus vulgaris* L.) plants cv. Nebraska during 2020 and 2021 seasons at the Experimental Farm of Horticulture Department, Faculty of Agriculture, Ain Shams University, Qalubia Governorate, Egypt. Results showed that all foliar treatments of selenium and silicon significantly enhanced all vegetative growth parameters, yield and yield quality attributes such as pod yield weight/plant and 100 seed weight, mineral contents in leaves, i.e., N, P, K and Ca as well as Se and Si in seeds as compared with control treatment. In conclusion, foliar spraying of common bean plants cv. Nebraska with Si at 2 mM or Se at 20 µmol enhanced growth, minerals content, yield and yield quality of the plants and subsequently improve the elements fortification at the food chain to humans.

Keywords: *Phaseolus vulgaris* L., Fabaceae, Beneficial elements, Elements fortification, Seed yield and Quality.

Introduction

Common bean (*Phaseolus vulgaris* L.) is one of the most valuable and popular leguminous vegetables worldwide; it is important in human diet and nutrition due to its high protein content and other dietary benefits. In Egypt, it is cultivated for local market and exportation with a total estimated harvested area of about 36.7 thousand hectares that produce about 144.8 thousand tons. In addition, it is widely cultivated in many countries with a total estimated harvested area of about 34.8 million hectares that produce about 27.5 million tons (FAOSTAT, 2020).

Recently, the importance of the beneficial elements for humans, animals, and plants has been clarified. One of the best strategies that maintain the supplement of the elements to humans and animals is the element fortification in plants; hence the supply of elements through the food chain (White and Broadley, 2009) In addition, in some countries such as China and Egypt, it has been found that there is a selenium deficiency in the diet. To solve this nutritional issue, selenium compounds are applied to the plants to enhance selenium contents at the edible parts of these plants (Kápolna et al., 2012). These compounds were applied as basal fertilizers through the root

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system or sprayed on the plant foliage (Feng et al., 2013).

Selenium (Se) is a natural element that exists in soil. It has been found that, it is essential for humans and animals (Fairweather-Tait et al., 2011). For plants, Se as a mineral nutrient do not fulfill Arnon and Stout's criteria for the essentiality of elements to plants, and it is considered to be a beneficial element; these elements could promote the plant growth in many plant species but are not absolutely necessary for the completion of the plant life cycle (Marschner, 2012). The beneficial elements for plants comprise selenium, cobalt, silicon and sodium. Selenium acts as an antioxidant that may alleviate abiotic stresses (Feng et al., 2013), i.e., salinity. Selenium regulates the reactive oxygen species (ROS) concentrations in plant cells by stimulating spontaneous dismutation of O_2^- to H_2O_2 by superoxide dismutase (SOD) through the interactions between selenium compounds and ROS *via* the control of antioxidant enzyme activity (Feng et al., 2013). Even under optimal growth conditions, ROS accumulated in plant cells especially in mitochondria and chloroplasts at the sites of electron transport (Zorov et al., 2014). Selenium contributes at forming selenoprotiens which play various roles at regulation of energy metabolism and redox during transcription and gene expression (Kong et al., 2005). In addition, selenium application enhanced the plant metabolism leading to yield increment in many plants including common bean (Corbo et al., 2018; Moussa and Hassen, 2018), broad bean (Boghdady et al., 2017) and peas (Žitná et al., 2018).

Silicon is a dominant element in the earth's crust reaches about 28.8 % based on the dry weight. Silicon is found in all living organisms comprise animals and plants (Farooq and Dietz, 2015). Silicon is found in the soil in form of silicon dioxide, silicate minerals and aluminosilicates, which are unavailable for plant absorption, while plants can absorb the silicon in form of monosilicic acid, which is the simplest form of soluble silicic acid (Ma and Yamaji, 2006). Silicon is a beneficial element for plants, although cereals uptake high amounts of silicon (Epstein, 2009) magnesium, and phosphorus, and in grasses often at higher levels than any other inorganic constituent. Yet except for certain algae, including prominently the diatoms, and the Equisetaceae (horsetails or scouring rushes). It has been found that the silicon element alleviates the biotic stress, i.e., pests and diseases (bacterial or fungal), and abiotic stress including drought, salinity, high temperature, freezing and metals toxicity (Epstein and Bloom, 2004). There are two ways in which silicon mitigates biotic and abiotic stresses *via* the polymerization of silicic acid resulting in the formation of solid amorphous hydrated silica or contributory in the formation of organic defense compounds through alteration of gene expression (Epstein, 2009). In addition, silicon application enhanced the uptake of nutrients; it increased the uptake of phosphorus, calcium and magnesium elements, and improved the carbohydrates in the rice plants (Liang et al., 2007).

In recent years, there has been a growing interest in supplying the plants with beneficial elements to enhance the plants' growth, yield and quality. Therefore, this study was designed to evaluate the impact of beneficial elements such as selenium and silicon on the vegetative growth, yield and quality of common bean (*Phaseolus vulgaris* L.) plants cv. Nebraska.

Materials and Methods

Plant Material and Experimental Site

Field experiment was conducted at the Experimental Farm of Horticulture Department, Faculty of Agriculture, Ain Shams University, Shoubra El-Kheima, Qalubia Governorate, Egypt (30°06'45.3"N 31°14'37.1"E) during the two successive growing seasons of 2020 and 2021. The aim of the study was to investigate the influence of selenium and silicon foliar applications on vegetative growth, SPAD reading, minerals content of leaves and seeds as well as seed yield of common bean (*Phaseolus vulgaris* L.) plants cv. Nebraska. Seeds were obtained from the Horticulture Research Institute, Agricultural Research Center, Ministry of Agriculture and Land Reclamation. Before sowing, the seeds were treated with commercial fungicides Amisto and Prevex-N which contain active ingredients Azoxystrobin 25% and Propamocarb Hydrochloride 72.2 %, respectively. Seeds were sown on 7th and 10th of September in both growing seasons of 2020 and 2021, respectively. The field was divided into furrows (rows) with 60 cm width and 4 m long. The seeds were sown in hills at 25 cm apart on one side of the rows. In each hill, two seeds were cultivated. Each experimental plot area was 12 m^2 comprises 5 rows.

In both seasons, all agricultural practices for common bean cultivation (irrigation, fertilization, weeding, pests and diseases control) were uniformly performed for all treatments as recommended by the Egyptian Ministry of Agriculture and Land Reclamation.

Foliar treatments

Seven foliar treatments were applied on the common bean plants; sodium selenite (Na_2SeO_3, MW 172.94) at levels of 10, 20 and 30 µM, and sodium silicate (Na_2SiO_3, MW 122.063) at levels of 0.5, 1 and 2 mM were dissolved at distilled water plus distilled water served as control treatment. The foliar spraying treatments were applied twice; the first one applied after 21 days from sowing seeds, then it was repeated after 14 days from the first application. During early morning, foliar sprayings were applied using a hand-held sprayer. The same amount of distilled water was sprayed to the control plants to avoid interferences with different moisture levels. The spraying solution was maintained just to cover completely the plant foliage.

Data recorded

Vegetative growth characteristics

A random sample of five plants from the two inner rows of each experimental plot was taken at 45 days after planting date to record the vegetative growth characteristics. Plant length was measured from the base of the stem to the tip of the longest leaf. Also, number of shoots and leaves per plant were counted, and the average leaf area was calculated as relation between area unit and fresh weight of leaves (Koller, 1972) using the following equation:

$$\text{Leaf area} = \frac{\text{Disk area x No. of disks x fresh weight of leaves}}{\text{Fresh weight of disks}}$$

Then in the laboratory, the plant samples were washed and the plant fresh weight was recorded. Afterwards, the plant samples were oven dried at 70°C until constant weight to record the plant dry weight.

SPAD readings

A portable chlorophyll meter (SPAD–502, Konica Minolta Sensing, Inc., Japan) was used to measure the leaf greenness of the plants. SPAD-502 chlorophyll meter is a non-destructive method, which can be used to estimate total chlorophyll amounts in leaves of plants (Neufeld et al., 2006). For each plant, the youngest fully expanded leaves of randomly five plants per replicate were selected, readings were taken at four locations on the leaf; two on each side of the midrib, and then averaged (Khan et al., 2003).

Mineral analysis of leaves and seeds

The mineral content of leaves and seeds were assayed. Leaf and seeds samples were oven dried at 70 C° until constant weight, then the dried samples were ground to fine powder to pass a 1 mm sieve. Afterwards, 0.1 g of the dried samples was taken and wet digested as described by Thomas et al. (1967), by using a mixture of sulphuric acid (H_2SO_4 98%) and hydrogen peroxide (H_2O_2 30%). The mineral content of leaves and seeds were assayed in the digested solutions. Total nitrogen was determined using Kjeldahl method as described by Piper (1950). Colorimetrically, phosphorus content was measured by using spectrophotometer using the ascorbic acid method as described by AOAC (2005). Moreover, potassium was measured by flame photometer as described by Page et al. (1982). Calcium and magnesium were measured by the Versenate (EDTA) method as mentioned by Tucker and Kurtz (1961). Selenium and silicon were also assayed in seed digested solution by using Inductively Coupled Plasma - Optical Emission Spectrometry (ICP-OES, Varian Vista MPX, Varian Inc., CA., USA) as mentioned by Rodushkin et al. (1999).

TABLE 1. Physical and chemical properties of the 0–30 cm soil layer in the experimental soil before common bean cultivation.

Physical and Chemical Properties							
Sand (%)	**Silt (%)**	**Clay (%)**	**Texture**	**pH**	**Ca^{++} (meq/l)**	**Mg^{++} (meq/l)**	**K^+ (meq/l)**
23.40	36.10	40.50	Clay	7.44	0.60	1.78	1.15
Na^+ (meq/l)	**Cl^- (meq/l)**	**CO_3^{--} (meq/l)**	**HCO_3^- (meq/l)**	**Si^+ (mg/kg)**	**Se— (mg/kg)**		
0.57	0.60	0	0.30	1.480	1.625		

Data presented as averages for the both growing seasons

Seed yield and seed quality attributes

The plants were harvested and the dried pods were collected after 110 days from sowing date from each experimental plot. Dried pods weight/plant, weight of 100 seeds, seed protein content was estimated by multiplying nitrogen percentage value in dried seed samples by conversion factor of 6.25 and the shelling percentage were measured. The shelling percentage was calculated by the following formula:

$$\text{Shelling percentage} = \frac{\text{Weight of the dried seeds}}{\text{Weight of the whole dried pods}}$$

Experimental Design and Statistical Analysis

The experiment was laid out as a randomized complete blocks design (RCBD) with three replicates. Foliar spraying treatments were randomly arranged within the block and each block consisted of 7 plots. Data were subjected to statistical analysis of variance procedure using one-way-ANOVA of the CoStat package program (Microcomputer Program Analysis, Version 6.303; CoHort Software, CA, USA). Duncan's multiple range test at 5% level of probability was employed to compare the significant differences among means of the treatments (Waller and Duncan, 1969).

Results

Vegetative growth characteristics

Data presented in Tables (2 and 3) clearly show that foliar application of Si at 2 mM gave the highest significant values of all recorded parameters of plant vegetative growth, i.e., plant length, number of branches/plant, number of leaves/plant, fresh and dry weights of plant and leaf area/plant in both growing seasons. In addition, the foliar application of Si at 1 mM showed also the highest values of plant length, number of leaves/plant and dry weight of plant. No significant differences were detected between 1 and 2 mM Si treatments in most cases in both seasons of 2020 and 2021. For the selenium foliar applications, the obtained results showed that the application of Se at level of 20 µmol revealed the highest significant values of number of branches/plant, number of leaves/plant and leaf area in the both growing seasons. However the foliar application of Se at 10 µmol on common bean plants showed the highest significant values of plant length in both growing seasons. On the contrary, the lowest significant values of all recorded vegetative growth parameters were obtained by the control treatment in both growing seasons. These results are in a good agreement with the previous studies which reported that the selenium and silicon applications significantly enhanced the vegetative growth parameters of various plants including common bean (Corbo et al., 2018; Moussa and Hassen, 2018), bean (Boghdady et al., 2017) and peas (Žitná et al., 2018).

SPAD readings

It is obvious from Table (4) that the foliar sprayings of selenium and silicon had no significant effect on the SPAD readings of the common bean plants when compared with the

TABLE 2. Effect of using selenium and silicon at different rates as foliar spraying on plant length, number of branches/plant and number of leaves/plant of common bean plants cv. Nebraska in 2020 and 2021 seasons.

Treatments	Plant length (cm)		Number of branches/plant		Number of leaves/plant	
	1st season	2nd season	1st season	2nd season	1st season	2nd season
Control	60.73 c	69.80 c	2.63 b	3.13 d	11.08 c	14.33 b
Se 10 µmol	69.27 a	90.80 a	2.80 b	3.73 ab	14.40 a	16.67 b
Se 20 µmol	64.60 b	76.17 b	3.07 a	3.87 a	13.90 ab	19.87 a
Se 30 µmol	64.40 b	68.33 c	2.83 ab	3.60 bc	13.20 ab	14.97 b
Si 0.5 mM	64.67 b	71.77 c	2.87 ab	3.40 c	12.88 b	16.77 b
Si 1 mM	68.57 a	87.63 a	2.80 b	3.82 ab	13.33 ab	21.28 a
Si 2 mM	69.83 a	91.33 a	2.87 ab	3.73 ab	13.48 ab	20.67 a

Means within each column followed by the same letter are not significantly different ($P \leq 0.05$) according to Duncan's multiple range test.

TABLE 3 Effect of using selenium and silicon at different rates as foliar spraying on plant fresh and dry weights and leaf area/plant of common bean plants cv. Nebraska in 2020 and 2021 seasons.

Treatments	Vegetative growth fresh weight (g)		Vegetative growth dry weight (g)		Leaf area/plant (cm^2)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season
Control	53.83 d	87.33 e	14.77 d	17.22 c	1678.69 c	1456.81 d
Se 10 µmol	65.83 b	102.53 d	19.69 abc	18.51 bc	1854.18 bc	2018.90 b
Se 20 µmol	67.33 b	121.33 c	18.76 bc	24.03 ab	2207.68 a	2202.78 a
Se 30 µmol	59.50 c	97.50 d	17.08 cd	17.77 bc	1734.97 bc	1734.31 c
Si 0.5 mM	67.25 b	96.00 d	22.54 a	17.92 bc	1873.61 bc	1967.19 b
Si 1 mM	71.67 a	132.58 b	21.52 ab	25.68 a	1954.20 ab	2001.30 b
Si 2 mM	72.00 a	167.17a	21.55 ab	26.76 a	1996.91 ab	2275.08 a

Means within each column followed by the same letter are not significantly different ($P \leq 0.05$) according to Duncan's multiple range test

control treatment in both growing seasons. In spite of no significant differences were realized among treatments, it is cleared that SPAD reading varies depending on the level of exogenous selenium concentration; hence under low concentrations, the SPAD reading was increased, while under high Se concentration, the SPAD reading decreased (Zafeiriou et al., 2022).

Mineral analysis of leaves and seeds

Results in Table (5) revealed that the foliar treatments of selenium and silicon at different rates in the both growing seasons significantly enhanced the percentages of N, P, K and Ca in the common bean leaves as compared with the control treatment. However, there was no significant effect of all foliar spraying treatments on Mg percentage in the leaves. In addition, the highest significant values of N% were obtained with Se 20 µmol or Si 2 mM treatments. For P%, Se 10 µmol treatment recorded the highest significant value in the first season, while Se 20 µmol treatment gave the highest significant value in the second season. Furthermore, Se 30 µmol, Si 1 mM and Si 2 mM treatments showed the highest significant values for K% in the first season, whereas treatment of Si 2 mM gave the highest significant value in the second season. The lowest significant values of N and P % were recorded with the control treatment. These results are in good agreement with those reported by Boghdady et al. (2017) on broad bean and Al-Saeedi (2018) on common bean.

On the other hand, other studies were conducted to evaluate the effect of selenium and silicon on plants under salinity stress. The obtained results coincide with Mahmood et al. (2016) on mung bean, AL-Kazzaz (2018) on broad bean, Ramos et al. (2020) on cowpea and Rady et al. (2019, 2021) on common bean who reported that selenium and silicon mitigate the salinity stress and enhanced the chemical and mineral constituents at the plant on common bean who reported that selenium and silicon mitigate the salinity stress and enhanced the chemical and mineral constituents at the plant.

Concerning results shown in Table (6), the results clearly indicate that all selenium and silicon foliar applications treatments had no significant effect of the percentages of N, P and K in the common bean seeds as compared with the control treatment in both growing seasons. However, the selenium and silicon foliar spraying treatments had significant effects on the Se and Si contents in the seeds. The highest significant values of silicon and selenium were recorded with Si 2 mM and Se 30 µmol treatments, respectively.

Seed yield and seed quality attributes

Data shown in Table (7) demonstrated that all selenium and silicon foliar application treatments significantly enhanced the pod weight/plant and the weight of 100 seeds as compared to the control treatment. The highest significant values of the aforementioned attributes were obtained with Se 20 µmol and Si 2 mM treatments in both growing seasons. However the lowest significant values were obtained with the control treatment in both growing seasons. On the contrary, data in Table (8) revealed that there were no significant differences between the values of protein percentage in dried seeds and shelling percentage of all selenium and

TABLE 4. Effect of using selenium and silicon at different rates as foliar spraying on SPAD reading of common bean plants cv. Nebraska in 2020 and 2021 seasons.

Treatments	SPAD readings	
	1st season	2nd season
Control	35.58 a	36.84 a
Se 10 µmol	37.01 a	37.34 a
Se 20 µmol	37.87 a	37.80 a
Se 30 µmol	36.90 a	37.12 a
Si 0.5 mM	38.17 a	37.47 a
Si 1 mM	37.87 a	37.98 a
Si 2 mM	37.14 a	38.23 a

Means within each column followed by the same letter are not significantly different ($P \leq 0.05$) according to Duncan's multiple range test

TABLE 5. Effect of selenium and silicon foliar spraying on macronutrients concentrations in leaves of common bean cv. Nebraska in 2020 and 2021 seasons.

Treatments	Nitrogen (%)		Phosphorus (%)		Potassium (%)		Calcium (%)		Magnesium (%)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Control	1.98 d	2.69 d	0.287 de	0.271 b	2.957 a	2.61 c	1.767 cd	1.760 b	0.312 a	0.270 a
Se 10 µmol	2.14 cd	2.85 bc	0.357 a	0.290 a	2.723 b	2.64 c	2.120 a	1.707 b	0.302 a	0.303 a
Se 20 µmol	2.49 a	3.01 a	0.270 e	0.292 a	2.703 b	2.83 a	1.817 bcd	2.227 a	0.299 a	0.297 a
Se 30 µmol	2.00 d	2.79 cd	0.327 b	0.291 a	3.060 a	2.62 c	1.717 d	1.853 b	0.292 a	0.277 a
Si 0.5 mM	2.03 d	2.80 bcd	0.293 cd	0.280 ab	2.630 b	2.69 bc	1.887 bc	1.813 b	0.281 a	0.303 a
Si 1 mM	2.31 bc	2.93 ab	0.310 bc	0.282 ab	2.973 a	2.77 ab	1.930 b	1.733 b	0.291 a	0.313 a
Si 2 mM	2.32 ab	3.02 a	0.320 b	0.284 a	2.977 a	2.89 a	1.953 b	2.213 a	0.288 a	0.310 a

Means within a column followed by the same letter are not significantly different ($P \leq 0.05$) according to Duncan's multiple range test

silicon foliar spraying treatments as compared with the control treatment in both growing seasons. These findings coincided with previous studies which reported that selenium and silicon foliar applications significantly increased the yield and productivity of various plants including common bean (Corbo et al., 2018; Moussa and Hassen, 2018; Rady et al., 2019 & 2021), bean (Boghdady et al., 2017), cowpea (Merwad et al., 2018) peas (Žitná et al., 2018) and mung bean (Mahmood et al., 2016)The increments in yield of the above mentioned plants may be attributed to the role of selenium and silicon in enhancing the vegetative growth of the plants, photosynthesis efficiency (Ekanayake et al., 2015) and nutrients uptake (Liang et al., 2007). In addition, selenium and silicon elements can regulate the levels of ROS accumulated in the plant cells.

Discussion

The Se and Si foliar application enhanced the vegetative growth parameters as mentioned in Tables (2 and 3). These increments in vegetative growth parameters may be attributed to the enhancement of the plant nutrient uptake such as nitrogen, phosphorus, potassium and calcium in the leaves as mentioned in Table (5). These nutrients play pivotal roles in improving the plant

TABLE 6. Effect of using selenium and silicon at different rates as foliar spraying on nitrogen, phosphorus, potassium, silicon and selenium contents in seeds of common bean plants cv. Nebraska in 2020 and 2021 seasons.

Treatments	Nitrogen (%)		Phosphorus (%)		Potassium (%)		Silicon (ppm)		Selenium (ppm)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Control	3.703 a	3.395 a	0.370 a	0.336 a	2.127 a	1.917 a	0.135 cd	0.062 d	0.111 c	0.105 c
Se 10 µmol	3.720 a	3.546 a	0.360 a	0.318 a	2.070 a	1.909 a	0.137 bcd	0.073 cd	0.133 b	0.129 b
Se 20 µmol	3.847 a	3.452 a	0.347 a	0.321 a	2.073 a	1.952 a	0.134 d	0.086 bcd	0.136 b	0.132 b
Se 30 µmol	3.810 a	3.412 a	0.373 a	0.339 a	2.047 a	1.998 a	0.140 bcd	0.050 d	0.155 a	0.145 a
Si 0.5 mM	3.660 a	3.384 a	0.357 a	0.299 a	2.110 a	1.985 a	0.143 bc	0.104 abc	0.115 c	0.106 c
Si 1 mM	3.677 a	3.498 a	0.367 a	0.321 a	2.173 a	2.046 a	0.144 b	0.118 ab	0.114 c	0.108 c
Si 2 mM	3.653 a	3.426 a	0.340 a	0.324 a	2.123 a	1.955 a	0.158 a	0.137 a	0.110 c	0.107 c

Means within each column followed by the same letter are not significantly different (P ≤ 0.05) according to Duncan's multiple range test

TABLE 7. Effect of using selenium and silicon at different rates as foliar spraying on pods weight/plant and weight of 100 seeds of common bean plants cv. Nebraska in 2020 and 2021 seasons.

Treatments	Pods weight/plant (g)		100 seed weight (g)	
	1st season	2nd season	1st season	2nd season
Control	66.50 e	105.33 d	132.16 e	98.14 d
Se 10 µmol	117.00 c	130.00 c	152.62 ab	122.30 c
Se 20 µmol	128.67 ab	166.67 a	155.10 a	141.07 a
Se 30 µmol	105.00 d	122.67 c	144.11 cd	102.39 d
Si 0.5 mM	115.00 cd	122.67 c	140.09 d	124.56 c
Si 1 mM	120.00 bc	146.67 b	148.12 bc	132.44 b
Si 2 mM	131.00 a	166.33 a	150.53 ab	143.22 a

Means within each column followed by the same letter are not significantly different (P ≤ 0.05) according to Duncan's multiple range test

growth and development; nitrogen biologically combined with carbon, hydrogen, oxygen, and sulphur to create amino acids, which are the building units of proteins and enzymes (Epstein and Bloom, 2004). Nitrogen also is important for the chlorophyll formation which is necessary for the photosynthesis process in the plants (Epstein and Bloom, 2004). Moreover, nitrogen encourages the uptake of other nutrients such as potassium and phosphorus (Epstein and Bloom, 2004), phosphorus play role in accumulation and release of energy associated with cellular metabolism since phosphorus plays a major role in energy storage and transfer *via* the molecules of ADP and ATP which are the sources of the energy that drives many chemical reactions within the plants (Marschner, 2012). Also, phosphorus acts as a structural element of nucleic acids (DNA

TABLE 8. Effect of using selenium and silicon at different rates as foliar spraying on protein percentage in seeds and shelling percentage of common bean plants cv. Nebraska in 2020 and 2021 seasons.

Treatments	Protein percentage		Shelling percentage	
	1st season	2nd season	1st season	2nd season
Control	23.15 a	21.22 a	78.00 a	77.96 a
Se 10 µmol	23.25 a	22.16 a	79.13 a	78.75 a
Se 20 µmol	24.04 a	21.58 a	78.77 a	78.56 a
Se 30 µmol	23.81 a	21.33 a	78.55 a	74.26 a
Si 0.5 mM	22.88 a	21.15 a	76.73 a	81.89 a
Si 1 mM	22.98 a	21.86 a	77.52 a	81.70 a
Si 2 mM	22.83 a	21.41 a	75.21 a	78.59 a

Means within each column followed by the same letter are not significantly different ($P \leq 0.05$) according to Duncan's multiple range test

and RNA molecules), and phosphorus play an important role in roots formation and flowering of the plants (Marschner, 2012). Potassium plays role in the translocation of carbohydrates in the plants, involved with enzyme activation within the plant, and control the transpiration process since it plays role at the turgidity of the stomatal guard cells.

The enhancement in the yield and yield quality parameters which reported in Tables (7 and 8) may be as result of the vegetative growth improvements as mentioned in Tables (2 and 3) or increment of nutrients in leaves as mentioned in Table (5)

Also, the enhancement in the vegetative growth parameters, yield and yield quality attributes may be attributed to the role of selenium at regulating the levels of ROS accumulated in the plant cells especially in mitochondria and chloroplasts at the sites of electron transport (Zorov et al., 2014). Also, selenium regulates the amount and activity of antioxidant enzymes; glutathione peroxidase (GSH-Px), Glutathione reductase (GR), Superoxide dismutase (SOD), Ascorbate peroxidase (APX) and catalase (CAT), and metabolites such as Glutathione (GSH) and ascorbate and decreased lipid peroxidation resulting in higher ROS scavenging capacity of plants (Feng et al., 2013). The selenium antioxidant activity improvement leads to photosynthesis amelioration, in its turn, the carbon assimilation increased (Ekanayake et al., 2015). Moreover, selenium supplement increased the osmotically active molecules such as total free amino acids and protein (Nawaz et al., 2016) Selenium enhances the uptake of nutrients (Feng et al., 2009), increases starch accumulation in chloroplasts and improves the root activity, and consequently stimulates water uptake (Proietti et al., 2013).

For silicon influence, the increment of the vegetative growth, yield, mineral content parameters may be as a result of the silicon role in enhancing the transpiration and stomatal conductance, photosynthetic efficiency, net CO_2 assimilation rate, antioxidant capacity and improving plant cells water (Pavlovic et al., 2021). Also, silicon enhances the nutrient uptake since it increased the uptake of phosphorus, calcium and magnesium elements in rice plants (Liang et al., 2007) leading to healthy status of plants that maximize the photosynthesis efficiency, and plays role in maintenance of plant mineral balance and plant water conservation (Zhu and Gong, 2014). In addition, silicon protects the plants from pest attacks hence it is accumulated and polymerized in the plant cells to form a mechanical barrier as silica – cuticle double layers (Teixeira et al., 2017). Furthermore, Si makes the plant leaves rougher in texture, since it increases leaf rigidity (Ouzounidou et al., 2016), increases the chlorophyll content and RuBisCo activity, and delays leaf senescence (Ma and Yamaji, 2006). The increase in leaf blade erectness facilitate light penetration subsequently higher photosynthesis

(Gong et al., 2003). Also, Si increases the vegetative growth, i.e., leaf area so more light will be available for photosynthesis process, and protects the chlorophyll pigment from destruction (Agarie et al., 1998).

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Conflicts of Interest

No conflicts of interest during this study.

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تأثير الرش الورقي بعنصري السيلينيوم و السيليكون على نمو وانتاجية نباتات الفاصوليا

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في الأونة الأخيرة برزت أهمية العناصر المفيدة للانسان، الحيوان والنبات. أن خاصية تعزيز العناصر بالنبات، هي إستراتيجية مفيدة يمكن أن تقوم بامداد هذه العناصر خلال السلسلة الغذائية للانسان والحيوان. وقد وجد أن العناصر المفيدة ربما يمكنها أن تقوم بتحسين نمو وإنتاجية النباتات وهي تشمل عنصر اللسلينيوم، السيليكون، الكوبلت والصوديوم. أن تقييم تأثير هذه العناصر على نمو ، انتاجية وجودة العـديد من النباتات الهامة أصبح نهج ومجال جديد للبحث.

تم إجراء تجربة حقلية لتقييم تأثير الرش الورقي بعنصرى السلينيوم بتركيز ١٠ ، ٢٠ و ٣٠ ميكرومول و السيليكون بتركيز ٠,٥ ، ١ و ٢ مللي مولار بالاضافة للرش بالماء كمعاملة مقارنة على النمو الخضرى ، محتوى لعناصر المعدنية في الأوراق والبذور، قـراءات المحصول وجـودته لنباتات الفاصوليا صنف نبراسكا خلال موسمي النمو ٢٠٢٠ و ٢٠٢١ بمزرعة التجارب الخاصة بقسم البساتين ، كلية الزراعة ، جامعة عين شمس، محافظة القليوبية، مصر.

أوضحت النتائج المتحصل عليها أن جميع معاملات الرش الورقي بعنصري السيلينيوم والسيليكون على نباتات الفاصوليا صنف نبراسكا قد أدت إلى حدوث زيادة معنوية في قيم القراءات الخضرية، محتوي الأوراق من عناصر النيتروجين ، الفوسفور ، البوتاسيوم و الكالسيوم بالإضافة إلى عنصرى السيلينيوم والسليكون في البذور ، وزن القرون / نبات ووزن ١٠٠ بذرة إذا ما قورنت بمعاملة المقارنة في كلا موسمي الدراسة. وكإستنتاج من الدراسة، نجد أن أفضل المعاملات هي الرش الورقي بعنصر السيليكون بتركيز ٢ ملليمولار أو عنصر السيلينيوم بتركيز ٢٠ ميكرومول حيث أدت تلك المعاملات إلى تحسين النمو، المحصول وجودته، كما أدت لتعزيز وزيادة المحتوى فى نسبة العناصر المفيدة في بذور الفاصوليا والتي تدخل في سلسلة الغـذاء للانسان.

الكلمات الدالة: *Phaseolus vulgaris* L ، العائلة البقولية، العناصر المفيدة، التعزيز بالعناصر، محصول وجودة البذور.