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Selenium and Silicon Fertilization in Soilless Grown Eggplant

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Abstract – **In the study, 10µM Se from sodium selenate (Na_2SeO_4) and 2.8 mM Si from potassium silicate (K_2SiO_3), each one alone or both together, were used for nutrition of greenhouse-soilless grown eggplant. The eggplant yield was increased by 16.4% in Se alone, 12.5% in Si alone and decreased by 8.2 % in Se+Si together. Silicon effects on plant growth were not significant somewhat reducing effects observed, however better effects of Se on leaf area, shoot fresh and dry weight were recorded. Selenium and Si were not significantly affected to the eggplant fruit physical properties, except firmness. These two elements especially Si increased eggplant fruit firmness. Selenium and Si contents of the fruit were increased by the treatments. This can be important especially for Se nutrition of the human. Leaf nutrients contents, for N, P, K, Ca, Mg, Fe, Mn, Zn, Cu, were adequate; there were no any deficiencies or toxicities under the Se and Si doses in this experiment.**

Keywords – **Selenium, Silicon, Soilless Culture, Plant Growth, Yield, Fruit Quality, Human Nutrition, *Solanum Melongena.***

I. INTRODUCTION

The key point of production in hydroponic cultivation is the matter of plant nutrition. Because the solid or liquid environments of root zone in which plants are grown are inert in terms of nutrients contrary to soil. Nutrients that plants need are given via the prepared nutrition solutions. In soilless cultivation, rates and compositions of nutrients show alteration in each plant species, even genotypes and different developmental stages of the plants. In this situation, plants are kept under control by what they are given with nutrition solutions in the soilless cultivation. In the traditional soil production, it is possible that extra nutrients from the soil may become a part of the activity, beyond the nutrients given to the soil through fertilizers. Reveal of positive effects of the silicon (Si) and selenium (Se) on plant nutrition apart from nitrogen, phosphor, potassium, calcium, magnesium, iron, manganese, zinc, copper, boron, and molybdenum since the recent studies conducted has lead us to this study.

Significant increase of yield and product quality due to Si practices during the growing is reported for the plants of barley, rice plant, and sugar cane, tomatoes, cucumber, soybean, and bamboo [1] Another significant characteristic of silicon is that it decrease the damage in the plant under biotic and abiotic stress conditions, and also increases resistance against the stress [2,3]. It was reported that when 1mM Si is used in greenhouse zucchini grown in hydroponic conditions, there is an increase in the plant's growing and development, and its strength against the oidium [4]. Foliar application of Si on leaves of bean plants by 300 ppm Si in the forms of K_2SiO_4 and $MgSiO_4$ on 30th, 60th and 80th days following the plantation have been done. Despite both forms of silicon have a booster effect on the plant growing parameters and the yield, the form of K_2SiO_4 was seen to have a more effective role than $MgSiO_4$[5]. It is reported that application of 0.12% Si into the leaves of chestnut, the photosynthesis and growth were increased [6]. In cherry tomato growing by applying Si in rockwool in a hydroponic environment in greenhouse, Si application into tomato increased the yield between 2.0 - 4.8% [7].

Selenium is an essential microelement for the human body. It is an element the deficiency in human and animal bodies of which cannot be put into risk for the growing-development and continuance of life [8]. An adult should take 55-70 µg of Se daily [9]. In the case of selenium deficiency, some diseases arise in human and animals. Immune system weakens, viral infections increase, and the cancer is triggered. However, intake of Se at higher doses may be toxic. Selenium content in soil on which agriculture is engaged is highly low. Since Se is essential in human and animal nutrition, this promotes the studies for increasing the Se contents of the strategic plants (cereals and vegetables: wheat, corn, potatoes, tomatoes, green vegetables-lettuce, etc.) used in food chain. The issued in such studies are the scanning and selection of Se-accumulating genotypes, or Se fertilizing during growing and increasing the Se content and these activities are called "Se biofortification" [10]. It is reported that selenium is a beneficial element for the plants and triggers plant growing when used at low concentrations [11, 12, and 13]. Selenium effects were studied [14] on the generative development of *Brassica rapa* L. among the *Brassica* plants, which is known as "Canola", which has the bio-fuel potential due to the high-oil content of seeds particularly, and the effects on blooming, seed yield, and seed vitality. The results are unbelievably impressive. Regarding this plant grown for its oily seeds, significant and highly beneficial increases were obtained in the Se content of seeds, and in the pollen vitality, seed amount, and seed germination ratio. Upon this, the authors reported that selenium gives positive benefits on not only the vegetative development but also the generative [14]. It was reported that application of 1.5 mg L^{-1} Se into the zucchini plants increased the yield [15]. It has been reported that the Se element has many positive and significant effects on health in human [16]. If selenium is taken 200 µg in human dietary programs, it significantly lowers the risk of liver, prostate and column cancers [16]. If selenium, a significant anti-oxidant for human health, is given via fertilization during the growing of plants constituting the basis of human-animal-plant nutritional food chain, it becomes an event to provide benefit for all the living being.

The aim of this study is, by adding Si and Se to nutrition solution in the greenhouse hydroponic vegetable growing, to increase the plant growing and development, yield and product quality. So far in the climate chamber with soil and hydroponics, it has been demonstrated that these two elements worked as a fertilizer in the model or small-scale yield and physiological trials conducted on pots in the greenhouse. In the study presented here, a real-scale trial has been planned in a way that the hydroponic greenhouse producers in practical can benefit from the results. Silicon and Se were used at appropriate doses alone and together in plant nutrition. They were grown comparing to the control plants to which Si and Se were not added.

II. Material and Method

The study was carried out at the 2013 spring cultivation period in a 500 m^2 glasshouse that is allocated for "Soilless cultivation" belonging to the Cukurova University Faculty of Agriculture, Department of Horticulture. The eggplant species used in the study is the Esmeralda F_1, which belong to the seed company of Vilmorin. Ready seedling was ordered. Plantation to the hydroponic system in the greenhouse was conducted on 14.02.2013. The study continued approximately 5 months, and it was ended on 01.07. 2013. The practices given below in 4 main subjects were carried out using the drip irrigation system under substrate culture in open and hydroponic cultivation.

1. Control: Nutrition solution applied to the plants was prepared according to the plant nutrients concentrations shown in the Table 1. This control solution did not include Si or Se.
2. Silicon Application: The nutrient solution applied to the plants comprised of the compound of potassium silicate (K_2SiO_3) including 2.8 mM Si as the last concentration [18].
3. Selenium Application: The nutrient solution applied to the plants comprised of the compound of sodium selenate (Na_2SeO_4) including 10µM Se as the last concentration [19].
4. Silicon and Selenium Application: The nutrient solution applied to the plants comprised of the compounds of potassium silicate (K_2SiO_3) and sodium selenate (Na_2SeO_4) including 2.8 mM Si + 10µM Se, respectively.

In the applications 2 and 4, the potassium from the 2.8 mM K_2SiO_3 was calculated and was provided from the K_2SO_4, and was added to the applications 1 and 3. For each of the application 500-liter tanks of nutrition solution was used. In the Si application, K_2SiO_3 was given from the separate tank, because it increases the pH of the nutrient solution. For each "Application", a water pump, meter, manometer, and filter are connected to the output of tank to which it is connected. In the greenhouse, the cucumber plants were grown with plantation density of 3.33 plant m^{-2}, at spacing of 150x90x25cm in the cocopeat bags with 100 cm height, 20 cm width, and 4 cm depth. For different applications in the study, plantation was performed by study design of random blocks at 4 replicate and 8 plants in each replicates. Cocopeat fibre bags were expanded by moistening with nutrition solution one day before the plantation.

III. Results and Discussion

In order to see the effects of the Se and Si nutrition on plant growth 117 day after planting; plant height, stem diameter, leaf number and flower number were recorded (Table 1). Plant height and leaf number were significantly higher in the Se alone application than the others. Stem diameter and number of flowers were similar in all the treatments and there were no any significant differences among them. Total shoot fresh, dry weights and leaf area were measured 140 days after planting at the end of the experiment (pruned leaves during the cultivation were also added), the highest positive effects on shoot growing and leaf area were obtained from the Se alone treatment and increased about 12.7%. However, Si alone treatment was decreased plant growth about 16.6%. Both elements Se and Si together were also decreased the plant growth by about 12.2% (Table 2). Since the compound K_2SiO_3 used as the Si source is highly alkali, it causes rise of pH in nutrient solution and substrate in the root zone inside the cocopeat bags, the high pH probably cause stress for the plants. The root area in the substrate was controlled continuously to prevent rise of pH values, and when necessary, the substrate was washed with a diluted-acidic nutrient solution. The pH values in the nutrient solution tanks with Si could only be decreased to about 6.5 with acid. When it was decreased below 6.5, gel-like small (0.3-1 mm) suspension particles due to the compound K_2SiO_3 in the solution were formed. These particles have the possibility to clog the nozzles of the drip irrigation. Moreover, these particles can form a gel-like layer on the substrate surface (within a few weeks). Nutrition solution brought together with the irrigation system sometimes survives on this gel-like layer, and cannot be penetrated within the substrate. In the hydroponics systems, when K_2SiO_3 is used as the Si source, these issues should be solved. May be another stress probably gel-like layer on the substrate surface could interfered water penetration into the substrate it could probably cause deficit of water sometimes. In soilles grown cucumber [17], Se nutrition, appears to have had a supportive effect on cucumber plant photosynthesis. However, the silicon considerably reduced the photosynthesis, stomatal conductance, transpiration rate and intercellular CO_2 concentration. When Se and Si used together the photosynthesis was increased may be due to the Se effects. It is reported that when 2.5 mM Si applied in the form of Na_2SiO_3 in the soybean cultivation, the increasing effect of the Si on growth as 3.4% in plant height and 2.9% in root height [19]. *Brassica napus* plants were grown with Selenate-Se and Selenite-Se as the Se sources, and application doses were 1, 2, 4 Se mg/kg soil for both sources [20]. The authors reported that there was decline in the growth parameters such as dried plant weight, plant height, etc. compared to the control plants at all doses of Selenate-Se, and also, the Selenite-Se source is as at least as the control however, did not increase the growth compared to the control. It was reported [21] the addition of Si (100 mg L^{-1}) could increase the chlorophyll content, RuBP carboxylase activity (ribulose-bis-phosphate), root fresh weight and dry weight in cucumber plants grown in a recirculating nutrient solution.

In this study, the eggplant yield was increased by 16.4% in Se alone, 12.5% in Si alone and decreased by 8.2 % in Se+Si together (Figure 1). In soilless grown cucumber reported that Se alone %12.4, Si alone %5.1 and both elements together Se+Si %8.4 have shown yield increases [17]. In soilless grown tomato, Se nutrition has increased the yield by 8.6%, however Si alone and Se+Si applications did not increased the tomato yield [18]. We link that the lower values of total yield in Si practices alone or Se+Si together to high-alkali in K_2SiO_3 used as Si source and secondly Si may cause lower photosynthesis, stomatal conductance, transpiration rate and intercellular CO_2 concentration. By using Si in rockwool grown soilless tomato yield increase was reported between 2.0-4.8% [7]. In tomato crop grown in a closed hydroponic system, 3.6% yield increase by Si was reported [22]. Greenhouse triploid watermelon was grown on sand-mulched soil and 1.8% yield increased was reported in comparison to control. Silicon had a positive impact on the parameters of watermelon fruit quality such as firmness and brix [23].

Some quality features were studied on the eggplant fruits. Physical fruit characteristics were not significantly affected by the Se and Si nutrition, except fruit firmness. As seen in Table 3, firmness was increased by both elements especially by Si. Silicon alone 44%, Se alone 28% and Se+Si 14% have shown fruit firmness increases compared to control. In tomato crop grown in a closed hydroponic system was reported that the contents of total solid solutes such as beta-carotene, lutein and lycopene contents of the fruit were significantly increased by Si supplementation. The Si also enhanced the fruit firmness and vitamin C in the tomato fruit [22]. Inclusion of Si to the nutrient solution of *Gerbera* resulted in improved overall crop quality with thicker flower stems and a higher percentage of flowers when compared to the plants grown with the standard nutrient solution [24].

Selenium and Si concentrations in eggplant fruit tissue have been increased, as expected, in the practices in which the concentrations of Se and Si elements are added into the nutrition solution. For the importance of Se in human dietary, this situation can be evaluated in the future. Being added into nutrition solution in soilless cultivation, the Se can have effect on the plant nutrition and on human who consumes it, via passing into the product. Selenium doses used in the study were not very high, and they can be increased in the future studies. Apart from this, in the applications in which the said elements including the control are not added, the Se and Si content were determined (Table 3). The Se and Si elements determined in the applications in which Selenium and Si are not added may have passed from the irrigation water, the content of fertilizer used, and the substrate used.

Leaf macro and micro nutrient concentrations of the eggplant plants were not affected significantly by the Se and Si treatments in the samples of the leaves that obtained from 140 days after planting at the end of the experiment. It seems that the application concentrations of the Se and Si did not negatively affect the nutrition of the eggplant plants during the growing period of this experiment (Table 4 and 5). Leaf nutrients contents (N, P, K, Ca, Mg, Fe, Mn, Zn, Cu) were adequate; there were no any deficiencies or toxicities under the Se and Si doses in this experiment. Similar effects of Se and Si on the other nutrient concentrations of leaves have been seen in the soilless grown cucumber [17] and tomato [18].

IV. Conclusion

Silicon effects on plant growth were not found to be significant, however better Se effects were observed in plant height, leaf number, shoot fresh, dry weights and leaf area. The eggplant yield was increased by 16.4% in Se alone, 12.5% in Si alone and decreased by 8.2 % in Se+Si together. Effects of the Se and Si applications on the physical characteristics of cucumber fruits were found to be insignificant, except fruit firmness. Selenium and Si contents of the fruits increased, this can be significant in the case of Se for human nutrition. Leaf nutrients contents (N, P, K, Ca, Mg, Fe, Mn, Zn, Cu) were adequate; there were no any deficiencies or toxicities under the Se and Si doses in this experiment.

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TABLES AND FIGURES

Table 1. Effects of the treatments on some plant growth parameters 117 day after transplanting

Treatments	Plant height (cm)	Stem diameter (mm)	Leaf number per plant	Flower number per plant
Contol	101.00 c	20.05	47.11 b	17.61
Selenium	115.66 a	19.42	49.88 a	18.94
Silicon	105.00 b	19.56	47.50 b	18.66
Selenium+Silicon	108.00 b	20.04	47.11 b	18.11

Table 2. Effects of Se and Si nutrition on total shoot fresh, dry weights and total leaf area 140 days after transplanting

Treatments	Leaf area (cm^{-2} $plant^{-1}$)	Shoot fresh weight (g $plant^{-1}$)	Shoot dry weight (g $plant^{-1}$)
Contol	41482 b	1765 b	269 b
Selenium	46747 a	1990 a	304 a
Silicon	35008 c	1490 c	227 c
Selenium+Silicon	36432 c	1551 c	237 c

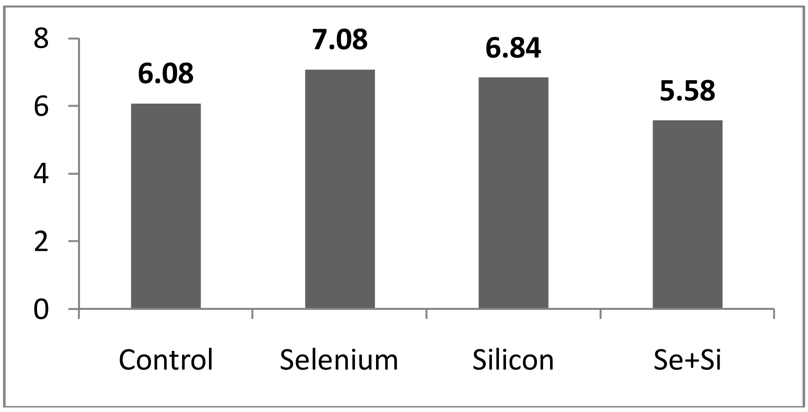

Figure 1. Selenium and Si nutrition effects on total yield of soilless grown eggplant.

Table 3. Effects of the Se and Si treatments on fruit properties

Treatments	Fruit weight (g)	Fruit diameter (mm)	Fruit height (mm)	Fruit volume (cm^3)	Fruit firmness (kg)	Se (μg g^{-1})	Si (%)
Control	167	57.04	13.15	255	3.87 b	303 a	0.303
Selenium	174	51.92	14.46	240	4.26 b	320 a	0.325
Silicon	177	50.82	13.31	264	5.57 a	255 b	0.368
Selenium+Silicon	165	57.91	13.53	204	4.40 b	293 a	0.348

Table 4. Effects of the Se and Si on macro nutrients concentrations of leaves at the end of the experiment (%)

Treatments	Nitrogen (N)	Phosphorus (P)	Potassium (K)	Magnesium (Mg)	Calcium (Ca)
Control	5.88	0.37	6.54	2.12	3.70
Selenium	5.59	0.41	5.94	2.45	3.57
Silicon	5.80	0.32	6.18	1.94	3.41
Selenium+Silicon	5.73	0.34	6.08	1.91	3.31

Table 5. Effects of the Se and Si on micro nutrients concentrations of leaves at the end of the experiment (ppm)

Treatments	Iron (Fe)	Manganese (Mn)	Zinc (Zn)	Cupper (Cu)
Control	58.8	37.0	65.4	21.2
Selenium	55.9	41.0	59.4	24.5
Silicon	58.0	32.0	61.8	19.4
Selenium+Silicon	57.3	34.0	60.8	19.1

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