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Effect of Se on the yield and Se status of Brussels sproutsgrown in hydroponics

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ABSTRACT

Influence of Selenium (Se) concentration in the nutrient solution on yield, quality, and Se status of Brussels sprout plants (*Brassica oleracea*, varGemmifera) was evaluated.The Brussels sprout plants were treated with six concentration of Se asselenate sodium ($Na_2 SeO_4$., 0, 2, 4, 8, 16 and 32 mg L^{-1}).Treatments were arranged in a completely randomize design with four replicates. The highest concentration of Se in the leaves, buds and stem was observed at the 32mg L^{-1} Se concentration. The total Se accumulation in percentage differed among different parts of plants. Total Se for the differ parts of plants ranged from 2.44 to 65.93% and old leaves accounted for the greatest proportion of total Se, followed by stem, young leaves, roots and buds in descending order. Increasing Se concentration increased Se allocation to the roots, while reduced the Se allocation to the buds. The size of buds increased by increasing Se concentration from 0 to 8 mg L^{-1}. However it was reduced in 16 and 32mg L^{-1} Se concentration. It can be concluded that Se supplements (8mg L^{-1}) improve yield, and Se concentration in the bud.

Introduction

Selenium (Se) is a naturally occurring trace element found in the Earth's crust, soils and minerals (Simmonsand Wallschläger, 2005). It is an essential trace nutrient important to humans and animals, whose deficiency andtoxic concentrations are very close to each other (Navarro-Alacron and Cabrera-Vique, 2008). Se hasbeen recognized as an integral component of different enzymes, such as glutathione peroxidase andthioredoxinreductase (Birringer et al., 2002). Chemically it is similar to sulphur (S), leading to nonspecificreplacement of S by Se in proteins and other sulphur components (Nowak et al., 2004). This resultsin non-functional proteins and enzymes.In plants, Se functions as an antioxidant (Hartikainen,2000). Plants take up Se from the soil primarily as selenate (SeO_4^{2-}) or selenite (SeO_3^{2-}) (Ellis and Salt,2003). Se can increase the tolerance of plants to UVinducedoxidative stress, delay senescence and promote the growth of ageing seedlings (Xue et al., 2001).

In Se rich areas plants that accumulate large amounts of Se are found. They are called accumulators. Activelygrowing tissues usually contain the largest amounts of Se (Kahakachchi et al., 2004). However, when absorbed in higher concentrations, Se can be harmfuland catalyse the oxidation of thiols and simultaneously generate superoxide (O^2-), which means it acts as a prooxidant (Stewart et al., 1999). The availability of Se for plants depends on soilproperties including pH, salinity and the content of $CaCO_3$ (KabataPendias, 2001). Temperature is alsoimportant factor affecting Se availability. In soils low with Se, plants absorb more Se at temperature higherthan 20 ºC. Plants from arid regions have more Se in their tissues as those from wet regions.

Se content of soils ranges from deficit quantities of 0.01 mg kg^{-1} at the Russian Plane to heavily toxic values of1200 mg kg^{-1} in organic soils at Meath, Ireland (Nowak et al., 2004). Slovenian soils are poor with Se (Kreft etal., 2002). In acid soils Se is mainly present in form of selenite, which has very low solubility and plantaviability. In alkaline soils, Se is oxidized to selenate, which is more soluble and more available for uptake(Navarro-Alacron and Cabrera-Vique, 2008). Se levels in soil generally reflect its presence in foodand Se levels consumed by human populations. Deficiency of Se can cause a heart disease,hypothyroidism and a weakened immune system (Ellis and Salt, 2003). Kahakachchi et al. (2004) reported thatSe has cancer chemopreventive properties for humans. Seed soaking or spraying of plants with Se solution may enrich the utilisable plant parts with Se compounds in concentrations of nutritional importance (Germ et al.,2007).

Plants in the family Brassicaceae play integral roles in the diets of the world's population. Brussels sprouts *(Brassica oleracea*, varJade cross E*)*are a cool season vegetablethat is considered a delicacy by many people. Brussels sprouts containsulforaphane, a chemical believed to have potent anticancer properties. Although boiling reduces the level of the anticancer compounds, steaming, microwaving, and stir frying does not result in significant loss.Brussels sprouts and other Brassica are also a source of indole-3-carbinol, a chemical which boosts DNA repair in cells and appears to block the growth of cancer cells.

Based on the literature thisinvestigation aimed to study the response of Brussels sprouts (*Brassica oleracea* var.Jade cross E) are grown in a floating systemwithapplication Selenium on theyield,and Se status.

Materials and Methods

The experiments were conducted in a greenhouselocated in Tabriz, Iran(1360 m above sea level, 38N, 46E), to study the effect of selenium on the yield,quality and Se status on Brussels sprouts (B*rassica oleracea* var. Jade cross E*)* grown in hydroponic cultures.After 72 h, germinated seeds (with 1 cm radicles)were transferred to plastic cupand the four-leaf stage into the larger plastic pots perlite both containing.After good growth of the plants, they were transferred to the floating system.The main medium experiment, the water medium in pots of 12 liter only nutrient solution is poured. Aeration was provided to the solution in each pot.The nutrient solution

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contained 300KNO_3, 455Ca $(NO_3)_2.4H_2O$, 10NH_4NO_3, 50KH_2PO_4, 250 $MgSO_4.7H_2O$, 1.3 H_3BO_3, 1.81$MnSO_4.4H_2O$, 0.22$ZnSO_4.5H_2O$, 0.08 $CuSO_4.5H_2O$, 0.02 $H_2MoO_4.H_2O$, 4 FeEDTA (concentrations are expressed in mg L^{-1}). After 10 week of grow plants to the nutrient solution wasadded with 0 (control), 2, 4, 8, 16 and 32 mg Se L^{-1} as sodium selenate(Na_2SeO_4).Experiments consisted of 6 treatment and 4 replications. After 14 weeks,when sprouts reached commercial maturity, i.e. 1-2 inches in diameter, plants of each replicate were harvested, and the fresh (FW), dry weight (DW), length, diameter and number of sprouts were determined.

In the dry weight the concentration ofSe was determined by the calorimetricmethodin the methdilazinehydrochloride,by thespectrophotometer,(MahaveerandJaldappa, 2000)(Table3).

Analysis was performed with the Software Statistical Package for the Social Science (SPSS) v. 16.0. Individual treatment means were compared with a Duncan's test to determine whether they were significantly different at the 0.05 probability.

Results and discussion

Vegetative Growth and sprout Yield

Data in table (1) indicated that application of Se at rates of (0, 2, 4, 8, 16 and 32 mg/l)significantly promoted vegetative growth representing the highest values of plant height, sprout number, dry sprout yield, sprouthigh, weight and diameter as well as total sprout yield as compared with the control.Over-application of Se may result in a decrease in yield. This may attribute tothe fact that in such conditions, vegetative growth of the aerial parts can be increased and hence, preventedtransferring of photosynthetically matters into the storage parts (sprout).

Data also demonstrated that application of selenium gave an increase in all growthcharacters as compared with the control which was in agreement with obtained results by MarjaTurakainen*etal*., 2004 Germ *et al*., 2007and Ozbolt*et al*., 2008. The highest value was noticed with selenium applied at rateof 8mg/l of Se as compared with 16, 32 mg/l of Se. The results achieved by Hartikainen*et al.* (2000) couldconfirm the fact that selenium interaction with plants depends on its concentration. At lower rates, seleniumstimulated growth of ryegrass seedlings, while at high doses it acted as pro-oxidant reducing yields and inducingmetabolic disturbances Also, Barbara Hawrylak-Nowak (2008) revealed that disturbances of growth andreduction of plant's biomass at the presence of high selenium concentrations in the nutrient solution may haveresulted from the disturbance of mineral balance of plants, namely accumulation of large amounts of phosphorusin shoot tissues of maize.

Table 1. Effect of Se supplementation on sprouts dry weight andfresh weight, sprouts number, length and diameter in Brussels sprouts (*Brassica oleracea* var. Jade cross E) plants grown for 14 weeks in greenhouse.

Se (mg/l)	Dry weight sprout (g)	Fresh weight sprout (g)	sprout number	sprout length (mm)	sprout diameter (mm)
0	6/06c	65/8c	68ab	15c	13/15c
2	12/81b	121b	66b	22b	16/05b
4	13/31b	125/5b	63b	21./ 8b	17/19b
8	17/57a	174a	74a	26/3b	21/09a
16	16/25a	160a	74a	22/2a	17/17b
32	6/11c	61/4c	67b	16c	16/28b

Data of each parameter followed by the same letter are not significantly different (P<0.05).

Data presented in figure (1) revealed that Se treatment at the 8mg/l levels significantly promoted growth parameters compared with control. Increased yield of Se treated plants suggested that Se may enhance thetranslocation of photoassimilates for sprout growth, acting as a strong sink for both Se and for carbohydrates. The positive impact of Se on the yield of Brussels sprout plants could be related to its antioxidative effect in delayingsenescence.Application of selenium at a rate of (8 mg/l Se) was more effectivecompared to selenium other rates. The highest value of this characteristic as affected by application of selenium was in agreement with data obtained by MarjaTurakainen*et al*., 2004.

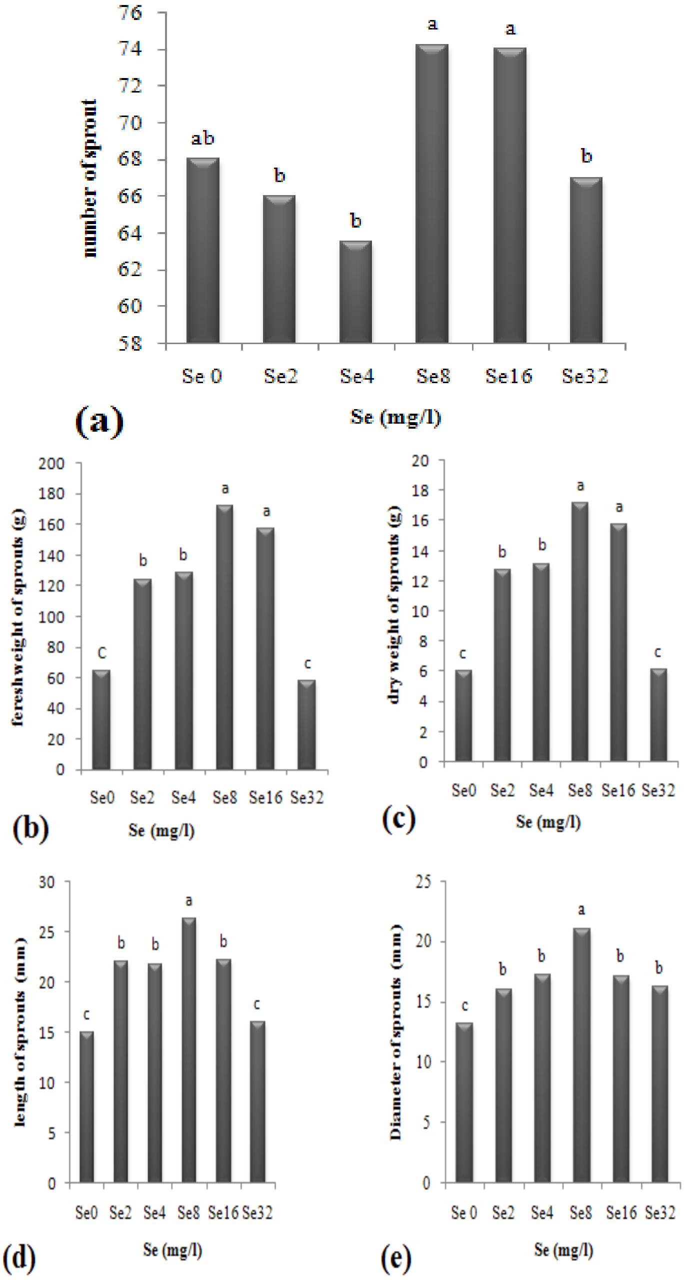

Fig. 1. Effect of Se supplementation(0, 2, 4, 8, 16 and 32 mg/l Se as Na_2SeO_4) on the number of sprout (a),FW of sprout (b), DW of sprout (c), length of sprout (d) and diameter of sprout (e) in Brussels sprout (*Brassica oleracea* var. Jade cross E) plants grown in floating system

Chemical Composition

Results in Table (3) showed the effect of Se application(0, 2, 4, 8, 16 and 32 mg/l Se as Na_2SeO_4) on Se content of all part plantsin floating system. Data showed that Se content in root, stem, young and old leaves and sprouts with increase Se concentration on nutrient solution increased (Table 3).These results are in agreement with Ducsay and lozek (2009).

Table 3. Effect Se supplementation on Se (mg/gDWt) in Brussels sprouts (Brassica oleracea var. Jade cross E)plants grown for 14 weeks in greenhouse

	Se				
Se (mg/l)	**root**	**stem**	**young leavs**	**old leavs**	**sprouts**
0	0c	0c	0c	0c	0c
2	0.6c	4.86bc	1.70bc	2.36b	1.11bc
4	1.45c	6.06b	2.05abc	2.46b	2.76abc
8	14.1b	6.71b	3.85ab	4.71a	4.51ab
16	20.7a	14.26a	4.00ab	5.66a	4.66ab
32	23.75a	16.21a	4.85a	5.96a	5.86a

Data of each parameter followed by the same letter are not significantly different ($P<0.05$).

In experiment, the highest Se content in the roots and stems at the 16 and 32 mg/land in young leaves at the 32 mg/l and in old leaves at the 8, 16, 32 mg/l and in the sprouts at the 32 mg/l Se concentration was observed. The lower Se content in all parts plants was observed at control (figure 3).

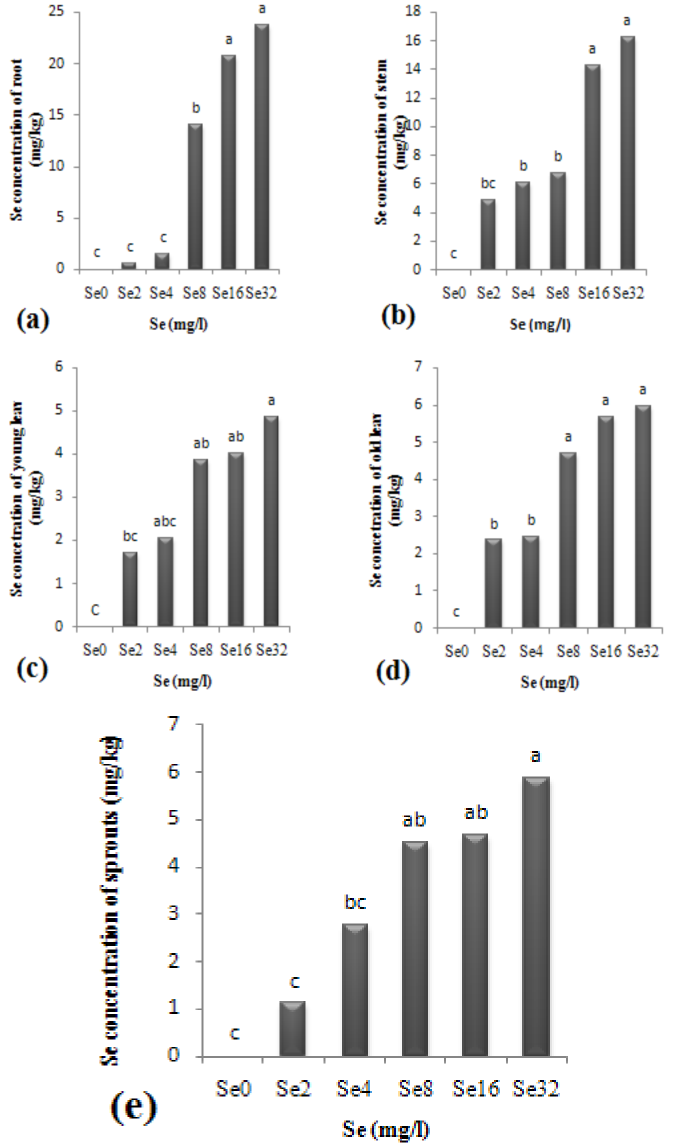

Fig. 3. Effect of Se supplementation (0, 2, 4, 8, 16 and 32 mg/l Se as Na_2SeO_4) on the Se concentration of root (a), Se concentration of stem (b), Se concentration of young leaves (c), Se concentration of old leaves (d) and Se concentration of sprouts (e) in Brussels sprout (*Brassica oleracea* var. gemmifera. C.v. Jade cross E) plants grown in floating system

Data in Tables (4) illustrated that application of selenium increased Se uptake in treatment plants compared with control. These results are in agreement with Ducsay and lozek (2009).It is noticeable that the increase of applied Se doses influenced its higher accumulation in plants which is in agreement with Adriano 1986. .Data revealed that application of Se from 8mg/l increased Se absorption in young and old leaves and sprouts but then decreased. Data also showed that absorption ratewith increase Se concentrationin roots and stems increased.

Table 4. Effect Se supplementation on the Se uptake (mg) in Brussels sprouts (*Brassica oleracea* var. gemmiferacv.Jade cross E)plants grown for 14 weeks in greenhouse.

Se (mg/l) / Se uptake (mg)	0	2	4	8	16	32
root	0	0.02	0.05	0.41	1.1	0.86
stem	0	0.21	0.24	0.44	0.52	0.61
young leaves	0	0.031	0.036	0.083	0.066	0.083
old leaves	0	0.54	0.43	1.27	1	1
sprout	0	0.018	0.036	0.077	0.073	0.035

Our results showed that in take of selenium vary between different organs of the Brusselssprouts. Most of the selenium absorption sold leaves, roots and stems and the lowest selenium absorption buds and young leaves were beginning. This is shown in Table 4. Germ etal.(2007)suggest that selenium effectively be transferred from the leaves to the potatoes. Turakainen (2007) reported that, compared with the leaves, roots and stolons the selenium concentration in the growing period not reduce tuber and this show is to transfer these lenium due to continued growth tuber potato and tuber potato canaccumulate to high levels of selenium. Leeet al. (1999) reported that selenium in the ediblespinachstoredlikeleaves.

Table 5. Effect Se supplementation on the Se distribution (%) in Brussels sprouts (*Brassica oleracea* var. gemmiferacv.Jade cross E)plants grown for 14 weeks in greenhouse

Se (mg/) / Sedistribution (%)	0	2	4	8	16	32
root	0	2.44	6.31	17.98	39.86	33.33
stem	0	25.64	30.30	19.29	18.84	23.64
young leave	0	3.78	4.54	3.64	2.39	3.21
old leave	0	65.93	54.29	55.7	36.24	1.35
sprout	0	2.19	4.54	3.37	2.64	38.75

According to Table5, the results show that is the different treatment levels selenium, the most selenium distribution in old leaves and the low selenium distribution in sprouts. Then of old leaves the most percent age distribution of selenium was observed in the root. Also then of sprouts the lowest percentage distribution of selenium showing in young leaves.

Zayed et al. (1998) reported that most of the selenium accumulation in stems, leaf and root tissues, but there are exceptions. Fertilizer application increased the concentration of selenium in broccoli (Sugihara et al, 2004). Huang (2005) stated that the concentration of selenium in the granulation tissue under high levels of selenium fertilization is very different ingenotype, genotype Brigidier lowest level of selenium in the granulation tissue compared with other genotypes. Turakainen (2007) observed that high concentrations of selenium in leaves, roots and stolons and the potato tuber will increase with increasing selenium. The highest concentrations of selenium in young leaves, roots and stolons showed that selenate added the benefit uptake.

Hu et al (2003) observed that the tea plant, sprayed with selenate the selenium content in the leaves will increase. Kahakachchiet al. (2004) showed that usually the selenium content in tissue developing further.

In addition, Se enrichment of Brussels sprouts not only could accelerate growth and improve its yield, of Brussels sprouts for human.

Conclusion

The aim of this research was to examine the effect ofselenium onyieldand Se status of Brussels sprout plants. The findingsof thisstudy indicatethat application of selenium gave an increase in all quantitative characters (dry weight, fresh weight, length, diameter and number of sprout) as compared with the control. Also, results showed the effect of Se application (0, 2, 4, 8, 16 and 32 mg/l Se as Na_2SeO_4) increased selenium content of young and old leaves plants as compared with the control treatments in floating system.The highest concentration of Se in the leaves, buds and stem was observed at the 32mg L^{-1} Se concentration. The total Se accumulation in percentage differed among different parts of plants. Total Se for the differ parts of plants ranged from 2.44 to 65.93% and old leaves accounted for the greatest proportion of total Se, followed by stem, young leaves, roots and buds in descending order. Increasing Se concentration increased Se allocation to the roots, while reduced the Se allocation to the buds. The size of buds, increased by increasing Se concentration from 0 to 8 mg L^{-1}. However it was reduced in 16 and 32mg L^{-1} Se concentration. It can be concluded that Se supplements (8mg L^{-1}) improve yield and Se concentration in the bud. In conclusion, our results suggest that the addition of Se in anutrient solution can be a useful system for providing enrichedleafy vegetables. In particular, a floating system can be used to modulate Se content in the nutrient solution and to growvegetables with the optimal Se content for human health.

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