Env. Biodiv. Soil Security **Vol. 1,** pp. 5- 31 (2017)

2

Review

The Interactions between Selenium, Nutrients and Heavy Metals in Higher Plants under Abiotic Stresses

Éva Domokos-Szabolcsy (1), **T. Alshaal** (2), **Nevien Elhawat** (3), **Neama Abdalla** (4), **A.R. dos Reis** (5) **and H. El-Ramady***

(1) Plant Biotechnology Dept., Debrecen Uni., Böszörményi Útca. 138, 4032 Debrecen, Hungary (Email: domokosszabolcsy@gmail.com)

(2) Soil and Water Dept., Faculty of Agriculture, Kafrelsheikh Uni., Kafr El-Sheikh, Egypt (alshaaltarek@gmail.com)

(3) Biological and Environmental Sciences Dept., Home Economics Faculty, Al-Azhar Uni, Egypt (Email: adel.nevien@yahoo.com)

(4) Plant Biotechnology Department, Genetic Engineering Division, National Research Center, 33-El-Behouth St., 12622 Dokki, Giza, Egypt (Email: neama_ncr@yahoo.com)

(5) Plant Physiology and Biosystems of Crop Production, Biosystems Engineering, Sao Paulo State University, Brazil (E-mail: andrereis@tupa.unesp.br)

Received: 17 / 4 / 2017
Accepted: 15 / 5 /2017

SELENIUM, the beneficial or quasi-essential element to higher plants, is an essential micronutrient for animals and humans as well as lower plants. in several countries around the world, about one billion of people are se-deficient and counteract this problem, e.g., brazil, thailand, china and egypt due to the low inherent se concentration in soils. therefore, different se forms have been used in different crops using foliar and soil application as well as seed priming to increase the se content in the edible parts of these crops. due to its physiolocial roles in higher plants, se has been used in counteracting various abiotic stresses including chilling, freezing, heat, drought, salinity, uv-b and heavy metals. concerning se and its interactions with some nutrients like cu, mo, zn and iodine, a very few studies have been published, so further studies are needed. on the other hand, nano-se and its roles in plant physiology under different abiotic stresses still also need further researches. therefore, this review will focus on the physiological importance of se and nano-se for higher plants under abiotic stresses as well as the interaction of se with some nutrients including cu, mo, zn and iodine and some heavy metals such as As, Sb, Cd, Cr, Hg and Pb.

Keywords : Selenium, Nano-Se, Higher plants, Abiotic stress, Heavy metals, Nutrients.

Introduction

Selenium (Se) was misidentified initially as tellurium by Klaproth and later in 1817 was discovered and named by the Swedish chemist J. Berzelius. This name was derived from the Greek goddess for Moon (Selene). The properties of Se lie between both adjacent sulfur and tellurium and it exists in different chemical forms including selenide, selenite, selenate, and elemental nano-Se etc. (Kabata-Pendias 2011; Kumar and Priyadarsini 2014). The importance of Se in human nutrition was documented in 1957 by Schwarz and Foltz (Schwarz and Foltz 1957). Later, the roles of Se in mitigating environmental stress have been extensively investigated in animals and humans but in higher plants still need more investigations (Feng *et al.* 2013a). Due to its several physiological roles in higher plants (Tamaoki *et al.* 2008; Pilon-Smits and Quinn 2010; Hasanuzzaman *et al.* 2010; Hajiboland 2012; Feng *et al.* 2013a; Pilon-Smits *et al.* 2014; El-Ramady *et al.* 2015a; Pilon-Smits 2015), Se has been used in counteracting various abiotic stresses including chilling, freezing, heat, drought, salinity, UV-B and heavy metals, but the associated mechanisms

---

* Corresponding author (Hassan El-Ramady: ramady2000@gmail.com)

DOI : 10.21608/jenvbs.2017.951.1001

are rather complicated and still remain to be fully elucidated (Feng *et al.,* 2013a). In higher plants, several beneficial and/ or toxic effects of Se on physiology and biology of these plants including their metabolism and growth have been well documented (Hasanuzzaman *et al.,* 2010; El-Ramady *et al*., 2015a). Moreover, a significant progress has been made in understanding Se behavior in higher plants including uptake, assimilation, and its metabolism (Pilon-Smits and Quinn 2010; Pilon-Smits 2015) as well as volatilization, toxicity and its tolerance (Feng *et al.* 2013a; Pilon-Smits *et al.,* 2014; Winkel *et al.* 2015). However, the mechanisms by which Se counteracts the environmental stresses are still not fully understood.

The most extensively investigated mechanisms for Se-mediated detoxification have been involved the antioxidative stress response. The relationships among enzymatic antioxidants including glutathione peroxidase (GPx), superoxide dismutase (SOD), catalase (CAT), ascorbate peroxidase (APx) and non-enzymatic antioxidants including glutathione (GSH), vitamin E and ascorbate as well as S-assimilation, different Se species, the uptake and redistribution of co-factors for some enzymes (*e.g.,* Cu, Fe, Mo, Mn and Zn) should be taken into account in future studies (Feng *et al.,* 2013a).

The recent review will basically cover Se physiology and biology in higher plants under different abiotic stresses. Se and its interactions with nutrients and heavy metals as well as effects of nano-Se on higher plants under these abiotic stresses will be also highlighted.

Physiological importance of Se and nano-Se for higher plants

It is well known that, abiotic stresses including nutritional deficiency, high light (UV-B), drought, high CO2, ozone (O3), heat, cold, chilling, freezing, salinity, flooding, soil compaction and heavy metals can have devastating or detrimental impacts on plant growth, yield and hence the agricultural production (Fig.1; Suzuki *et al.* 2014; Nakabayashi and Saito 2015; Ramegowda and Senthil-Kumar 2015). According to recent studies, the plant response to combinations of more than two stress conditions is seldom and can not be directly distinguished from the individual response of these plants to different applied stresses. Furthermore, a very high degree of complexity in plant responses can be found and resulted from the simultaneous occurrence of different stresses (Suzuki *et al.* 2014). Concerning the combined stresses and their effects on plants, a few studies have been published including Suzuki *et al.* (2014), Nakabayashi and Saito (2015), Pandey *et al.* (2015), Ramegowda and Senthil-Kumar (2015) and Mahalingam (2015). Various aspects of Se and nano-Se roles in counteracting abiotic stresses in different plant species have been published by several authors (Table 1). These abiotic stresses include salinity, drought, high or low temperature as well as stresses resulting from high or low Se and nano-Se levels.

It has been identified 25 selenoproteins and discovered their physiological role for lower plants bacteria and algae), animals and human metabolism, in which Se is an enzymatic cofactor (Kumar and Priyadarsini 2014). Se has been recognized as a constituent of selenoenzymes including glutathione peroxidase (GPx), thioredoxin reductases (TR), and proteins with unknown functions that are involved in maintaining the cell redox potential (Rayman 2000). Several experimental attempts have been made to recognize these selenoproteins also in higher plants but it is still open question (Mora *et al*. 2015). However, many studies have been showed that Se in higher plants improves the plant growth, increases the tolerance against biotic and abiotic stress (Pennanen *et al.* 2002) and improves other physiological parameters (Turakainen *et al.* 2006; Pilon-Smits *et al.* 2009; Mora *et al.* 2015; Handa *et al*. 2016).

Concerning the main physiological benefits of Se in higher plants, it could be summarized the following results of some published studies using the proper Se concentration (Table 1):

(1) Enhancement of plant germination, growth and dry matter accumulation (Turakainen *et al.,* 2004; Djanaguiraman *et al.,* 2005; Ramos *et al.,* 2011; Mao *et al.,* 2015; Owusu-Sekyere *et al.,* 2013; Cappa *et al*. 2014; Hawrylak-Nowak *et al.,* ,2015; Jain *et al*. 2015; Li *et al*., 2015; Longchamp *et al*., 2015; Sasmaz *et al*., 2015; Zhao *et al*., 2016; Feng *et al.,* 2016; Longchamp *et al*., 2016).

(2) Increases carbohydrate or starch accumulation in chloroplasts (Turakainen 2006; Malik *et al.,* 2011; Hashem *et al*., 2013; Hajiboland *et al.,* 2015);

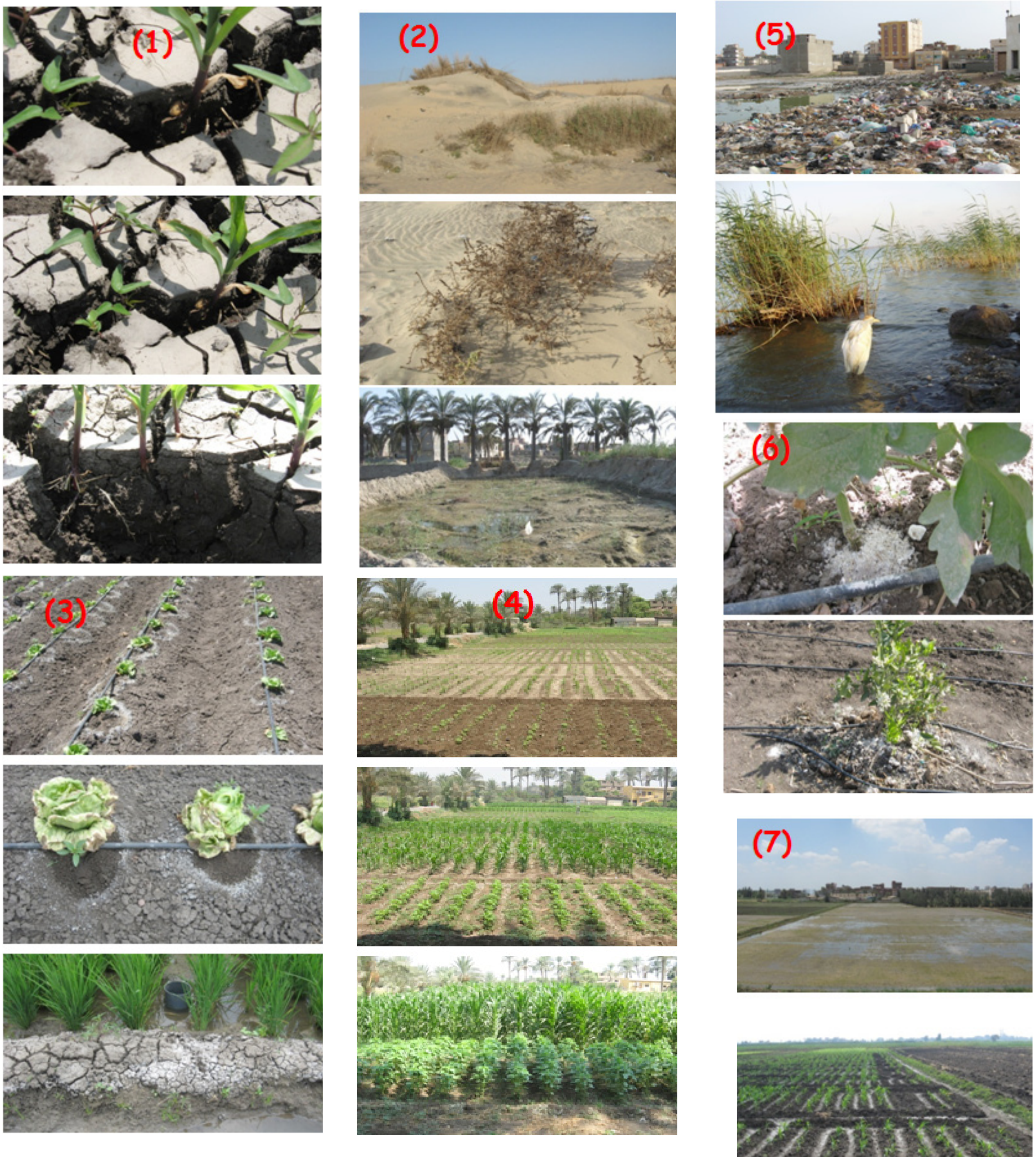

Fig. 1 : Some environmental abiotic stresses including drought under salt affected soils and temperature more than 50 ºC during August 2015 (photo 1), low soil fertility or nutrient deficiency under sandy soils (photo 2), soil salinity (photo 3), soil management including tillage by time (photo 4), environmental pollution (photo 5), over-use of fertilizers (photo 6) and flooding (photo 7) in Kafr El-Sheikh and Giza, Egypt (Photos by El-Ramady)

(3) Regulates the water status in plants (Yao *et al.,* 2009a; Soleimanzadeh 2012; Hajiboland *et al.,* 2014; Nawaz *et al.,* 2015a, b).

(4) Enhances production of stress hormones (*e.g.,* ethylene, jasmonic acid and salicylic acid) or Se involves in both salicylic and jasmonic acid pathway of plants stress response (Oraghi Ardebili *et al.,* 2014; Iqbal *et al.* 2015b; Pilon-Smits 2015);

(5) Improves plant tolerance to oxidative stress (Cartes *et al.* 2011; Ibrahim 2014; Iqbal *et al.* 2015b; Bachiega *et al. 2016)*

(6) *Activates antioxidant* defense system as well as cytosolic calcium and ROS in higher plants (Yuan *et al.,* 2013a; Talukdar 2013; Diao *et al.,* 2014; Saidi *et al.,* 2014; Naz *et al.,* 2015; Feng *et al.,* 2016)

TABLE 1: A survey for main studies on various aspects of Se and nano-Se role in counteracting abiotic stresses in different plant species.

Plant species	Stressor level (Exp. medium)	Se form & dosage (exposure period)	Different effects of Se on stressed plants and associated potential mechanisms (Reference)
Salinity or salt stress			
Glycine max var. L17	100 mM NaCl (pot experiment)	25, 50 mg Se L^{-1} (7 d)	The alleviating effects of Se and/or salicylic acid (0.5 mM) had significant inducing effects on enzymatic (POD, CAT, SOD); non-enzymatic (AsA) antioxidant system (Oraghi Ardebili et al. 2014)
Lycopersicon esculentum M. (2 varieties)	100 mM NaCl (hydroponics)	0.05 mM Se as Na_2SeO_3 (10 d)	Promotes growth, photosynthesis of tomato seedlings, enhances chloroplast antioxidant defense system: SOD, APX, GR, GPx, POD, DHAR; AsA, GSH (Diao et al. 2014)
Brassica napus L. var Pactole	2, 4, 6 g L^{-1} saline solution (pot exp.)	2.5, 5, 10 mg L^{-1} Se as Na_2SeO_4 (15 d)	Protective effect of Se on canola subjected to salinity stress was observed in increased plant growth, yield and changes in photosynthetic pigments, proline, regulation of antioxidative enzyme activities: SOD, POD, CAT (Hashem et al. 2013)
Brassica napus L. cv. BINA Sharisha 3	100, 200 mM NaCl (petri plates)	25 mM Se as Na_2SeO_4 (48 h)	Decreased MDA and H_2O_2 levels and chlorosis, Se increased the tolerance of the plants to drought-induced oxidative damage by enhancing their antioxidant defense: SOD, GR, CAT, GPx, as well as AsA, GSH (Hasanuzzaman and Fujita 2011)
Cucumis sativus L.	2 g L^{-1} NaCl (7 d in pot exp.)	1 mg L^{-1} Se as Na_2SeO_3 (14 d)	Increased activities of POD, CAT, SOD, APX, PAL; reduction in electrolyte leakage, MDA content (El-Shalakany et al. 2010)
Cucumis sativus L. cv. Polan	50 mM NaCl (14 d in hydroponics)	5, 10, 20 mM Se as Na_2SeO_4 (14 d)	Improved the growth rate, photosynthetic pigments, decreased Cl^- ions, enhanced antioxidative capacity: APX, MDHAR, DHAR, GR, as well as AsA, GSH (Hawrylak-Nowak 2009)
Drought or water deficit stress			
Triticum aestivum L. cv. Pasban-90	60 % from field capacity (FC) (pot experiment)	40 mg Se L^{-1} as Na_2SeO_4, foliar application	Improved uptake of some nutrients (Se, Fe and Na); increased wheat yield, osmoprotectants, antioxidant activity: CAT (11%), POX (58%), APX (27%) (Nawaz et al. 2015a)
Triticum aestivum L.	60 % from field capacity (FC) (lysimeter exp.)	5.1, 0.50, 0.48 mg L^{-1} Se as Na_2SeO_4 by seed priming, fertigation and foliar spray, resp.	Enhancement in the production of osmoprotectants (proline, total soluble sugars, total soluble proteins, total free amino acids); increased activity of antioxidant enzymes (POX, CAT, APX); the foliar spray of Se was more effective than Se fertigation and Se seed treatment (Nawaz et al. 2015b)
Olea europaea	Deficit water regime (pot and field exp.)	300 mg L^{-1} Se as Na_2SeO_4	Under drought stress, Se induced pollen viability and germination, strongly counteracted the reactive oxygen species accumulation (Tedeschini et al. 2015)
Triticum durum L.	30 % from FC (pot exp.)	10 µg L^{-1} Se as Na_2SeO_4 (28 d)	Se application improves some physiological parameters (photosynthetic rate, accumulation of osmolyes and water use efficiency) but did not change significantly plants biomass or water relation parameters (Hajiboland et al. 2014)

Triticum aestivum L. cv. Giza 168	Stop irrigation 50-70 days from sowing (field and Lab exp.)	Soaking of grains in 5 and 10 mg L^{-1} Se as Na_2SeO_4	H_2O_2 and MDA contents were decreased whereas the activities of antioxidant enzymes (CAT, SOD); content of non-enzymatic antioxidants (AsA, GSH) were increased resulting in elevated membrane stability index and root viability (Ibrahim 2014)
Hordeum *vulgare* L. cv. Rihane-03	Drought for 35 days exposure (field exp.)	30 g Se ha^{-1} as Na_2SeO_4 (10 d)	MDA, H_2O_2 remained unchanged under Se supplmented water-deficit plants; an efficient scavenging following enhancement of POD, SOD, APX, CAT, GPx activities (Habibi 2013)
Olea europaea L. cv. Maurino	Irrigated at 25% available water (pot exp.)	Foliar spray 50 and 150 mg Se L^{-1} as Na_2SeO_4	Increases photosynthesis and fruit yield; regulate the water status of trees, the activities of APX, CAT, GPx; reduced the content of MDA (Proietti et al. 2013)
Temperature (Heat, chilling and freezing) stress			
Triticum aestivum L. (2 cultivars)	Heat stress at 38 ± 2 °C (field exp.)	Foliar 2, 4 mg Se L^{-1} as Na_2SeO_4 (at heading stage)	Increased enzymatic (CAT, APX); non-enzymatic (carotenoids, anthocyanins, AsA contents) antioxidants; decreased oxidants: H_2O_2, MDA (Iqbal et al. 2015a)
Brassica napus L.	Stress at 38 °C for 24 or 48 h (hydroponics)	25 µM Se as Na_2SeO_4 (10 d)	Enhanced enzymatic (MDHAR, DHAR, GR, GPx, CAT, Gly I, II); nonenzymatic (proline, AsA, GSH) antioxidant components of defense subjected to heat stress; decreased oxidants: H_2O_2, methylglyoxal, MDA (Hasanuzzaman et al. 2014)
Sorghum bicolor L. Moench	40/30 ºC for 45 days (pot exp.)	Foliar 75 mg Se L^{-1} as Na_2SeO_4, after 63 days from sowing	Se decreased membrane damage *via* enhancing antioxidant defense (SOD, CAT, POX); increase photosynthetic rates, grain yield; decrease reactive oxygen species content under heat stress (Djanaguiraman et al. 2010)
Cucumis sativus L. cv. Polan F1	Chilling stress: 10°C/5°C for 24 h (hydroponics)	2.5, 5, 10, 20 µM Se (14 days)	Se (at 2.5–10 µM) modified the physiological response (Chl a,b, carotenoids) of cucumber to chilling stress, causing an increase in proline content in leaves and diminishing lipid peroxidation (MDA) in roots (Hawrylak-Nowak et al. 2010)
Selenium (Se) stress			
Lemna *minor* L.	Hydroponic system	0.5, 1, 2, 5, 10 mg Se L^{-1} as Na_2SeO_3 (7 weeks)	Higher concentrations of Se (2, 5, 10 mg L^{-1}) negatively affect Chl a, b, electron transport system activity; duckweed under 10 mg Se L^{-1} survived for 14 days and contained 6.5 mg g^{-1} DM; survived for 21 days contained 19.5 mg Se g^{-1} DM; higher than 10 mg L^{-1} is the toxic level for duckweed (Mechora et al. 2015)

Oryza Sativa L. genotype PR 118	Co-exposed with ascorbic acid (50 µM) in hydroponics	1, 2.5, 5 mg Se kg^{-1} as Na_2SeO_4 (10 days)	Se at 5 ppm inhibits of roots and shoots by 47% 60%, Se-stressed plants supplemented with AsA showed significant up-regulation of MTs, total thiols, GST activity to reduce the toxic effects of Se (Sharma et al. 2014)
Oryza sativa L.	Field experiments	10, 20, 50, 100 g Se ha^{-1} as Na_2SeO_3	50 g Se ha^{-1} recorded the highest grain yield; photosynthesis (Pn, Gs, Tr) or chlorophyll fluorescence parameters could be used to determine the Se status for production of Se-rich rice (Zhang et al. 2014)
Brassica oleracea L. var. *capitata*, cv. Pandion	65 days after emergence of plants (field ex.)	Soil (2 µg Se L^{-1}) and foliar (20 mg L^{-1}) as Na_2SeO_4	At harvest, Se concentration was lower than 0.1 mg Se kg^{-1} DW (in control), while plants treated with 20 mg Se L^{-1} contain 5.5 mg Se kg^{-1}; Se enriched cabbage could be used in human nutrition; Chl a, b, Tr, anthocyanins, photosynthetic rate did not change significantly for both Se methods (Mechora et al. 2014)
Solanum lycopersicon L. cv. Margoble	For 24 h and 5 days (Hydroponic and pot exp.)	5, 10, 25, 50 µM Se as well as foliar 2 mg per plant as Na_2SeO_4 (20 – 40 days)	Low Se doses (5 and 10 µM) *via* roots stimulate synthesis of phenolic compounds in leaves, reduced of Mo, Fe, Mn, and Cu in roots; higher Se doses (25 and 50 µM Se) enhance leaf GSH by 3−5-fold; Se supply *via* foliar spray (up 20 mg Se plant^{-1}) result in Se-biofortified tomato fruits, enhancing antioxidant, flavonoids (Schiavon et al. 2013)
Oryza sativa L. ssp. japonica	0.525, 10.5, 21 g Se ha^{-1} (pot and field exp.)	2, 6, 10, 20, 30, 40, 50, 60 mg L^{-1} as Na_2SeO_3 (11 d)	Major Se species in rice include SeMet and SeCys (54 and 21% of total Se, resp.); spray with 10.5 g Se ha^{-1} increase Se content in grain rice from 0.03 µg g^{-1} to 1.54 µg g^{-1} without any Se symptoms toxicity; promote rice seedling growth by activating endogenous antioxidant system (Wang et al. 2013)
Nano-Se stress			
Lycopersicum esculentum Mill. cv. Halil	Temperature stress: 10, 25, 40 ºC for 24 h (hydroponic)	2.5, 5, 8 µM Se as Na_2SeO_4 & nano-Se 1, 4, 8, 12 µM (3 d)	Se and nano-Se can improve tomato shoot fresh and dry weight and diameter, root fresh and dry weight and root volume under high and/or low temperature stress; Se and nano-Se increased relative water content and root volume significantly after a short-term of high and/or low temperature stress (Haghighi et al. 2014)
Arundo donax L. 2 ecotypes Blossom and 20SZ	Nano-Se: 100 mg L^{-1} Se as *Lactobacillus casei* (*in virto* exper.)	0.1, 1, 10, 50, 100 mg L^{-1} Se as Na_2SeO_4 (8-16 d)	Both *Arundo* ecotypes could uptake and accumulate nano-Se however in lower concentration comparing to the selenate; the toxic level of selenate was 20 and 50 mg L^{-1} for Blossom and 20SZ accumulating 920 and 896 mg kg^{-1} Se in clusters resp. (Domokos-Szabolcsy et al. 2014)

(7) Delay of plant senescence (Djanaguiraman *et al.,* 2004; Pezzarossa *et al.,* 2014; Wu *et al.,* 2016b)

(8) In accumulator species protects plants from fungal infection and herbivores including aphids, caterpillars, spider mites and thrips (Hanson *et al.,* 2003, 2004; Freeman *et al.,* 2007, 2009; Quinn *et al.,* 2010; El Mehdawi and Pilon-Smits 2012; Alford *et al.,* 2012; El Mehdawi *et al.,* 2015; Pilon-Smits *et al.,* 2016).

(9) Alleviation of abiotic and biotic stresses such as UV-B radiation, low and high temperatures, and heavy metal toxicity (Hasanuzzaman *et al.,* 2010; Feng *et al.,* 2013a; Mora *et al.,* 2015) as well as plant diseases (Kumar *et al.,* 2015; Wu *et al.,* 2016a; Zhang *et al.,* 2016).

It is worth to mention that, very few studies have been conducted regarding different physiological benefits of nano-Se on higher plants (Premarathna *et al.,* 2010; Domokos-Szabolcsy *et al.,* 2012, 2014; Haghighi *et al.,* 2014). It has been reported that, nano-Se has a higher efficiency in upregulating Selenoenzymes and exhibits less toxicity than selenite (Wang *et al.,* 2007). There is still open question related to the biological effects of this form of Se in higher plants. It is also well documented that, nano-Se has a distinguished effect on rooting of different plants such as giant reed and tobacco (El-Ramady *et al.,* 2015a).

Therefore, it could be concluded that, Se and nano-Se have a great role in plant physiology. Several different physiological benefits of Se on higher plants have been documented whereas nano-Se is still in needing for more and more studies.

Antioxidative effects of Se and its roles under abiotic stresses.

It is demonstrated that, different beneficial effects of Se in higher plants subjected to different stress conditions has been attributed to increased antioxidant activity (Hasanuzzaman *et al.,* 2010).

Se can promote growth and development of plants as well as increase the resistance and antioxidant capacity of higher plants under different abiotic stresses (Djanaguiraman et al. 2005), where it can increase plant resistance against oxidative stress caused by free oxygen radicals or ROS (Hassanuzzaman *et al.,* 2010). Several in vitro and/ or field experiments have been shown that Se may interact with other elements such as Al, Sb, As, Cd, Pb and Hg thus this may reduce the toxicity of Heavy metals (Yasin *et al.,* 2015c).The factors driving these relationships between Se, soil characterization including SOM and pH as well as characterization of these elements are not fully clear and further studies are mandatory to elucidate the role of soil and different climate variables in driving these relationships (Winkel *et al.,* 2015; El-Ramady *et al.,* 2015d,e).

Furthermore, some plant species grown on Se-enriched media have shown enhanced resistance to certain abiotic stresses such as.

(1) Drought (Germ *et al.,* 2007; Yao *et al.,* 2009a, b; Hasanuzzaman and Fujit 2011; Bañuelos *et al.,* 2011; Sajedi *et al.,* 2011; Yao *et al.,* 2012; Habibi 2013; Proietti *et al.,* 2013; Nawaz *et al.,* 2013, 2014; Khattab *et al.,* 2014; Hajiboland et al. 2014; Emam *et al.,* 2014; Nawaz *et al.,* 2015a,b),

(2) Salinity (Hawrylak-Nowak 2009; Hasanuzzaman *et al.,* 2011; Bañuelos *et al.*, 2011; Hashem *et al.,* 2013; Oraghi Ardebili *et al.,* 2014; Diao *et al.,* 2014),

(3) Temperature including chilling (Chu *et al,* 2010; Hawrylak-Nowak et al. 2010), low and high temperature (Akladious 2012; Hasanuzzaman *et al.,* 2014; Haghighi *et al.,* 2014; Iqbal *et al.,* 2015a)

(4) Heavy metals (Van Hoewyk 2013; Kaur *et al.,* 2014; Tedeschini *et al.,* 2015; Gu *et al.,* 2016) including Al (Cartes *et al.,* 2010; Sae-Lee *et al.,* 2012), Sb (Feng *et al.,* 2011, 2013b; Ding *et al.,* 2015; Feng *et al.,* 2016), As (Malik et al., 2012; Hasanuzzaman and Fujita 2013; Kumar *et al.,* 2013, 2014, 2015; Hu *et al.,* 2014b; Han *et al.,* 2015; Pandey and Gupta 2015), Cd (Lin *et al.,* 2012; Barrientos *et al.,* 2012; Elguera *et al.* ,2013; Feng et al. 2013c; Ojeda *et al.,* 2013; Ding *et al.,* 2014; Wang *et al.,* 2014; Wu *et al.,* 2014; Mozafariyan *et al.,* 2014; Hawrylak-Nowak *et al.,* 2014; Hu *et al.,* 2014a; Saidi *et al.,* 2014; Liu *et al.,* 2015a; Thiruvengadam and Chung 2015; Tang *et al.,* 2015; Issam *et al.,* 2015; Iqbal et al., 2015b; Bao *et al.,* 2016; Wan *et al.,* 2016), Cr (Qing *et al.,* 2015), Pb (Mroczek-Zdyrska and Wójcik 2012; Yuan *et al.,* 2013b, 2014; Hu *et al.,* 2014a), Mn (Saidi *et al.,* 2014), Hg (Zhang *et al.,* 2013; Zhao *et al.*, 2013, 2014;Wang *et al.,* 2014; Zhang *et al.,*

2014; Zhang 2014; Li *et al.,* 2015; Yin *et al.* 2016), Ni (Hawrylak *et al.,* 2007; Gajewska *et al.,* 2013),

(5) UV-B stress (Yao *et al.,* 2010a, b; Yao *et al.,* 2013; Mostafa and Hassan 2015) and

(6) Plant senescence (Djanaguiraman *et al.,* 2004, 2005; Liu *et al.,* 2011; Pezzarossa *et al.,* 2014; Wu *et al.,* 2016b).

some studies have discussed the different mechanisms of se behavior under different stresses in higher plants (e.g., feng *et al.,* 2013a; van hoewyk 2013; ahmad *et al.,* 2015; detar *et al.,* 2015). using antioxidants upregulation and its enzymes, exposure to se has been linked at optimal levels to the reduction of various ros (feng *et al.,* 2013a), inhibition of uptake and translocation of heavy metals, changing in heavy metals speciation and rebuilding of cell membrane, chloroplast structures as well as recovery of the photosynthetic system. at high levels of se, its oxyanions can be also a source of the oxidative stress (van hoewyk 2013; detar *et al.,*2015). in relation to the role of se in preventing of heavy metals toxicity, it is involved the reduction of heavy metals toxicity by inhibiting their uptake and/or translocation (feng *et al.,* 2013a). on the other hand and under drought stress, two roles can be expected from se; decreasing the oxidative damage resulting from ros by production of the compatible solutes and improving the tolerance of plants to drought by increasing sod, gpx, cat activities protecting plants against oxidative stress (ahmad *et al.,* 2015).

Several studies have been implicated the antioxidative effects of nano-Se for animals (Zhang *et al.,* 2001; Pelyhe and Mézes 2013; Rezvanfar et al. 2013; Suchý *et al.*, 2014; Sarkar *et al.,* 2015) including mice (Wang *et al.,* 2007; Zhang *et al.,* 2008; Bhattacharjee *et al.,* 2014; Rastgoo and Sadeghi 2015; Abd-Allah and Hashem 2015), sheep (Xun *et al.,* 2012; Sadeghian *et al.,* 2012; Kojouri *et al.,* 2012), goat (Shi *et al.,* 2010, 2011), chicken (Cai *et al.,* 2012; Hu *et al.,* 2012; Mohapatra *et al.,* 2014; Boostani *et al.,* 2015; Radwan *et al.*, 2015; Selim *et al.* ,2015), fish (Sarkar *et al.,* 2015; Khan *et al.,* 2016), whereas a very few studies have been recoreded for higher plants (Haghighi *et al.*, 2014; El-Ramady *et al.,* 2015a). Recently, the general effects of nano – particles on plants include plant growth, and its cell structure as well as both physiological and biochemical functions have been reported (Rico *et al.,* 2015). Moreover, the role of these nano – particles in antioxidant defense system in plants includes the effects on photosystems and some plant enzymes (CAT, POD, SOD, APx, GR and DHAR) as well as some low molecular weight antioxidant thiols (e.g., GSH) and ascorbate.

Therefore, it could be concluded that, Se has a distinguished role in increasing resistance and antioxidant capacity of higher plants. It strengthens the antioxidative capacity in higher plants by preventing the reduction of tocopherol concentration and by enhancing SOD activity. After Se addition to forage plants, it may not only increase the yield of plants but also improve their nutritive quality in many ways. It could be also summarized that, Se acts as an antioxidant, inhibiting lipid peroxidation via increased levels of thiols and GSH. It could be also suggested that, Se is either an antioxidant or it activates plant protective mechanisms, thereby alleviating oxidative stress and improving heavy metals uptake in higher plants. Optimal Se supply is favorable for growth of some plants (like wheat seedlings) during drought condition. The growth and physiological responses of seedlings were different depending on the Se concentration.

The interactions between Se, nutrients and heavy metals

The remediation process of different contaminated soils with multiple pollutants or contaminants is a difficult issue and thus it is compulsory to develop and sustain novel customized strategies for this remediation (Tripathi *et al.,* 2015). Therefore, it is very important to investigate the interaction between different nutrients in the context of biofortification and phytoremediation. According to the recent studies, Se has a few studies concerning the interaction with some nutrients including Cu, Mo, Zn, and iodine with exception for S. Their different properties comparing with Se are summarized in Table 2 as well as a survey of the recent studies for this interaction in Table 3. On the other side, several publications related to Se detoxification of some toxic heavy metals including Sb, As, Cd, Cr, Pb and Hg are presented in Table 4. Therefore, different relationships between Se and its role in detoxification of these heavy metals as well as the interaction between Se and some other nutrients (S, Cu, Mo, Zn and iodine) will be highlighted in this section.

TABLE 2. Some selected physical, chemical and biological properties of selenium comparing with sulfur, copper, iodine, molybdenum and zinc in higher plants.

Properties or items (unit)	**Copper (Cu)**	**Iodine (I)**	**Molybdenum (Mo)**	**Selenium (Se)**	**Sulphur (S)**	**Zinc (Zn)**
Discoverer (year)	Sommer (1931)	B. Courtois (1811)	P. Hjelm (1781)	J. Berzelius (1817)	von Sachs, Knop (1865)	Marggraf (1746)
World mine production in 2014 (metric tons)	18,700,000	31,600	266,000	2,275	72,400,000	13,300,000
Abundance in the Earth's crust	55 mg kg^{-1}	0.25-0.5 mg kg^{-1}	1.2 mg kg^{-1}	0.05 mg kg^{-1}	0.06 – 0.1 (%)	70 mg kg^{-1}
Abundance or usual soil content	20 mg kg^{-1}	2.8 mg kg^{-1}	0.5□5.0 mg kg^{-1}	0.33 mg kg^{-1}	0.01 – 0.1 (%)	63 mg kg^{-1}
Ranking of abundance in earth crust	26	63	58	69	14	24
Most important minerals	Chalcopyrite: $CuFeS_2$, Malachite: $Cu_2(OH)_2(CO_3)$, Cuprite: Cu_2O	Lodargirite (AgI) and marshite (CuI)	Molybdenite: MoS_2, Molibdite: MoO_3	Klockmanite: CuSe, Clausthalite: PbSe, Tiemannite: HgSe	Gypsum: $CaSO_4\,2H_2O$, Pyrite: FeS_2, Galena: PbS	Sphalerite: (Zn, Fe)S, Smithsonite: $ZnCO_3$
Common valence states	+1 and +2	−1 (+1 to +7)	+2, +4 and +6	-2 and +2	-2, 0, +2,+4, +6	+2
Density at 20°C, g cm^{-3}	8.94	4.93	10.2	4.79	2.07	7.13
Melting point (° C)	1083	113.7	2,617	217	112.8	419.6
Functions in Plants	Constituent of superoxide dismutase (SOD)	Component of di-iodotyrosine, triiodothyronine, antioxidant system	Component of enzymes: nitrogenase and nitrate reductase	Constituent of glycene reductase and glutathione peroxidase	Component of 3 amino acids, glucosides, coenzyme A, vit. B1	Component of some enzymes: dehydrogenase, proteinase, SOD
Principal forms for plant uptake	Cupric cation (Cu^{2+})	Iodide (I^-), iodate IO^-	Molybdate (MoO_4^{2-})	Selenate (SeO_4^{2-}) or selenite (SeO_3^{2-})	Sulphate (SO_4^{-2})	Zinc (Zn^{2+})
Essentiality for animals and plants	Essential for both	Essential: animals, beneficial: plants *	Essential for both	Essential: animals, beneficial: plants	Essential for both	Essential for both
Critical or sufficient level in plant leaf	1.0 – 5 mg kg^{-1} DW	0.1 mg kg^{-1} DW	0.1 – 1.0 mg kg^{-1} DW	0.1 – 2.0 mg kg^{-1} DW	0.1 – 0.5 % DW	15 – 30 mg kg^{-1} DW
Leaf toxic level, DW	15 – 30 mg kg^{-1}	0.5□1.0 mg kg^{-1}	1000 mg kg^{-1}	5.0 – 30 mg kg^{-1}	0.5 – 0.7 %	100 – 300 mg kg^{-1}
Uptake by plants and its transporter(s)	Active (Cu^{2+}): Cu transporters (proteins and gene families)	Iodine uptake through roots and leaf stomata; carriers halide-specific	Active (MoO_4^{2-}): sulphate transporter (Sultr 5;2) and MOT1	Passive (SeO_3^{2-}; by phosphate transporter), active (SeO_4^{2-} & SeMe): sulphate transporter	Active (SO_4^{-2}): sulphate transporter (Sultr5;2)	Active (Zn^{2+}): metal chelators (phytochelatin; metalothionein), Zn^{2+} transporters
Movement in soil	Mass flow	Mass flow (IO_3^-)	Mass flow and diffusion	Very mobile in soil by mass flow (SeO_4^{-2})	Mass flow (SO_4^{-2})	Mass flow and root interception
US recommended daily allowances for human	0.9 mg	150 µg	45 µg	55 µg	None specified	8 –11 mg

Source: Compiled from Mengel et al. (2001), Jones (2003), White and Broadley (2005), Jones (2005), Kabata-Pendias and Mukherjee (2007), White and Brown (2010), Kabata-Pendias (2011), Kirkby (2012), Fuge (2013), El-Ramady *et al.* (2014a,b), USGS (2015), Mitra (2015), Tatsuo (2015) and Kabata-Pendias and Szteke (2015).

Abbreviation: SeMe, selenomethionine

* According to Mengel *et al.* (2001), iodine is essential for the marine brown alga *Patalonia fascia*

TABLE 3: A survey for main studies on various aspects of Se interaction with some nutrients including S, Cu, Mo, Zn and iodine in different plant species.

Plant species	Co-application nutrient (medium)	Se form & dosage (exposure period)	Subject or scope for the study and its results (Reference)
Selenium and iodine interaction			
Lactuca sativa L. cv. Melodion	Iodine: 7.88 µM I as KIO_3 (NFT hydroponics)	Selenium: 6.33, 19 µM Se as Na_2SeO_4 (interval 7 d)	A limiting factor for the development of agro-technical methods of I and Se application is poor recognition of its interaction with respect to plant growth and metabolism; foliar application of Na_2SeO_4 + KIO_3 decreased level of Ca, Mg and Fe in roots, synergistic interaction of IO_3^- on SeO_4^{2-} uptake by leaves; foliar application of I together with Se improved SeO_4^{-2} uptake by leaves; transport of I and Se may occur from leaves to roots through phloem (Smolen *et al.*, 2014)
Triticum aestivum L. (Jordao) and *Triticum durum* Desf. (Marialva)	Iodine: 10 µM I as KI (field condition) Se added at both booting and grain filling stage	Selenium: 4, 20, 100 g Se ha^{-1} (or 0.2, 1, 5 mg L^{-1}) as Na_2SeO_4 and Na_2SeO_3	Foliar Se fertilization of Portuguese wheat cultivars through foliar treatment at booting and grain filling stages in presence of iodine; presence of potassium iodide does not seem to affect the Se accumulation in mature grains for cultivars and stages; foliar of Se can increase Se contents in mature grains up to 15 and 40 times for Marialva and Jordao, respectively, when compared to control (**Galinha** *et al.*, **2013**)
Microalga *Chlorella sorokiniana*	Iodine: 0.15 – 4 mg I mL^{-1} as KI and exposure for 4 h	Selenium: 0.02– 0.5 mg Se mL^{-1} as Na_2SeO_4 repeated three times	The microalga *Chlorella sorokiniana* can be used for the bio-accumulation of both Se and I in the production of functional food enriched in these elements; accumulating 1.2 mg g^{-1} within 24 h under exposure of iodide (0.15 mg mL^{-1}) and Se can be accumulated up to 3 µg g^{-1} by the alga after 100 h of exposure to 50 µg mL^{-1} of selenite in the culture medium (**Gómez-Jacinto** *et al.*, **2012**)
Selenium and sulfur interaction			
Triticum aestivum L.	Exper. I: 150, 300 mg S kg^{-1} harvested at 70 d (pot exper.) Exper. II: 0.1, 1, 2 mmol L^{-1} S as $MgSO_4$ $7H_2O$ (hydroponics)	Exper. I: 15 mg Se kg^{-1} as Na_2SeO_3 (7 d) Exper. II: 1 µmol L^{-1} Se as Na_2SeO_3 and Na_2SeO_4 $10H_2O$ (24 h)	Pot and hydroponic experiments were conducted at wheat seedling stage to study effects of applied S on the uptake of Se by plant; application of 150 mg kg^{-1} S reduced Se in wheat shoots (47 %) and roots (45%); S treatment changed soil pH (max. decrease of 0.52 units) and OM content (max. increase of 0.96 g kg^{-1}), thereby reduced soluble Se, increased Fe/Mn oxide bound Se; the content of Se in crops can be effectively controlled by increasing S-fertilizer applications in the high Se regions (**Liu** *et al.*, **2015b**)
Rape (*Brassica napus* L.)	Exper. I: 0.02, 0.1, 0.5, 2.0 mM as $MgSO_4 \cdot 7H_2O$ Exper. II: 0.1 mM sulphate Exper. III: 0.5, 2 mM (hydroponic)	Exper. I: 1 µM as Na_2SeO_3 or Na_2SeO_4 $10H_2O$ (24 h) Exper. II: 0.1, 0.5, 1, 5 10 µM SeO_3^{-2} or SeO_4^{-2} (2 h) Exper. III: 5 µM selenite/ selenate (7 d)	Se translocation factor significantly reduced by up to 46.4 and 60.5 % with increasing selenite and selenate in solution resp., while sulphate had effect only on Se translocation in selenate treatment; Se absorption capacity of rape supplied with selenite or selenate depends on sulphate concentration; sulphate is involved in the root to-shoot translocation of Se in *B. napus* supplied with selenate, but not selenite; correct selection of Se fertilizers depends on applied S-fertilizer, effective Se resources and the attenuation of environmental pollution arising from chemical fertilization (**Liu et al. 2015c**)
Plant species	**Co-application nutrient (medium)**	**Se form & dosage (exposure period)**	**Subject or scope for the study and its results (Reference)**

Stanleya pinnata and *Brassica juncea*	Sulfur: 0.5, 5 mM in combination with Se (hydroponics)	Selenium: 10, 20 µM as Na_2SeO_4 (3 days)	Se accumulation was ~10-fold with increasing sulfate supply in *B. juncea*, while *S. pinnata* only had a 2–3-fold difference in Se uptake between the highest (5 mM) and lowest sulfate (0 mM) treatments; Se/S ratio was generally higher in hyper-accumulator than the non-hyperaccumulator; transcript levels of *Sultr1;2* and *2;1* and *APS1,2, and 4* were generally much higher in *S. pinnata* than *B. juncea*, and the species showed differential transcript responses to S and Se supply (**Schiavon** *et al.* ,**2015**)
Selenium and copper interaction			
Pakchoi (*Brassica chinensis* L., Qinbai 2)	Cupper: 200, 400, and 800 mg kg^{-1} Cu as $CuSO_4$ (pot experiment)	Selenium: 2.5, 10, 20 mg Se kg^{-1} as Na_2SeO_3 (14 d)	Soil enzymes inhibited by single Cu or Se as well as Cu and Se combined pollution in different degrees: nitrate reductase > urease > CAT > alkaline phosphatase; The joint effects of Cu and Se on CAT showed synergism at low concentrations and antagonism at high concentrations; the opposite was observed for urease activity; synergism showed for nitrate reductase activity both with and without plant treatments (**Hu** *et al.* , **2013**)
Selenium and zinc interaction			
Broccoli (*Brassica oleracea* L.)	Zinc: 6.59 ppm $ZnSO_4.7H_2O$ (pot experiment)	Selenium: 0.5, 1, 2, 4 mg Se L^{-1} as both Na_2SeO_4 and Na_2SeO_3 (50 d)	Se inhibited germination of broccoli at doses above 50 and 100 mg L^{-1} for selenite and selenate, resp.; Se ameliorates effect of Zn deficiency on growth of broccoli; Zn reduced toxicity of Se at high Se doses; Zn may exert a Se detoxification effect at high Se doses, while Se may exert a sparing/substitution effect for Zn under Zn deficiency; at high Se levels (up 4 mg L^{-1}): biomass, water use, photosynthesis and gas exchange inhibited with selenite (more toxic than selenate) with high values in presence of Zn (**Mao** *et al.* **, 2015**)
Wheat (*Triticum aestivum* cv. Reska)	Zinc: fertilizer by 1 g kg^{-1} $ZnNO_3$ (pot experiment)	Se sprayed: 20 mg L^{-1} Se as Na_2SeO_4 or 3 mg Se per plant and 15 mg per pot (before flowering)	Since Se is assimilated in plants *via* S assimilation pathway, over-expression of sulphate transporters in Zn treated plants might be the reason for more efficient Se assimilation; double biofortification with Zn and Se may be a feasible strategy to efficiently coordinate the mineral quality of wheat grain due to alteration of sulphate metabolism in the presence of Zn (**Germ** *et al.* ,**2013**)
Selenium, sulfur and molybdenum interaction			
Astragalus racemosus, A. bisulcatus and *A. drummondii, A. convallarius*	Molybdate: 12, 24, 48 mg L^{-1} as Na_2MoO_4 (*in vitro* exper.)	Selenium: 1.6, 3.2 mg L^{-1} as Na_2SeO_4 (7 weeks)	Differences between Se hyperaccumulators and non-accumulators in Se, S and Mo interactions (in uptake mechanisms); sulfate transporters in hyperaccumulating *Astragali* appear to have higher sulfate specificity over other oxyanions, compared to nonaccumulators and *A. racemosus* may have a transporter with enhanced selenate specificity relative to sulfate or molybdate (**DeTar** *et al.,* **2015**)
Stanleya pinnata, (CO and CA ecot.) *Brassica juncea* L. Czern. (Cv. PI 426314)	Sulfate: 0.5, 5 mM S as Na_2SO_4 (pot experiment)	For *S. pinnata*: 10, 20, 40, 80 µM Se as Na_2SeO_4 For *B. juncea*: 10, 20, 40 µM Se as Na_2SeO_4 (twice/ week for 5 months)	Selenate may outcompete molybdate for transport better than sulfate; interactions among Mo, S and Se happen at level of various enzymes involved in sulfate assimilation, such as ATP sulfurylase, which may act on molybdate and selenate in addition to sulfate; *S. pinnata* contains a modified sulfate transporter with a higher specificity for selenate; at high Se levels *B. juncea* had significantly more Mo in roots and mature leaves than without Se (**Harris** *et al.,* **2014**)
Selenium, iodine and zinc interaction			
Zea mays L., *Glycine max* L., *Solanum tuberosum* L., *Brassica rapa* L., *Triticum aestivum* L., and *Brassica napus* L.	(1) Soil applied: 0.21, 22.7 and 0.59 kg ha^{-1} for Se, Zn and I (2) Foliar applied: 0.23, 0.45, 0.68, 0.91, 1.14 kg Zn ha^{-1} as $ZnSO_4.7H_2O$ (field trial)	(1) Soil applied: 0.5 kg Na_2SeO_4 ha^{-1}, 0.46 kg Na_2SeO_3 ha^{-1}, 100 kg $ZnSO_4.7H_2O$ and 1 kg KIO_3 (2) Foliar applied: 4, 20, 30, 46, 60 g Se ha^{-1} as selenite	Soil application of Se, Zn, and I was not effective in increasing the concentrations of other micronutrients (B, Cu, Fe and Mn); soil-applied selenate and foliar-applied selenite were found to be effective for Se biofortification; foliar zinc sulphate is effective in biofortifying winter wheat, and soil-applied Zn is effective in increasing the Zn concentration in cabbage leaf and canola seed; soil-applied I was found to be only effective in increasing I concentration in cabbage leaf; agronomic biofortification of the crops with Se as soil-applied sodium selenate was unaffected by co-application of Zn and/or I (**Mao** *et al.,* **2014**)

TABLE 4: A survey for main studies on various aspects of Se interaction with some heavy metals including Sb, As, Cd, Cr, Pb and Hg in different plant species.

Plant species	Stressor level (Exp. medium)	Se form & dosage (exposure period)	Different effects of Se on stressed plants and associated potential mechanisms (Reference)
Antimony (Sb)			
Oryza sativa L.	1, 5, 9 mg Sb L^{-1} as $KSbC_4H_4O_7$ 0.5 H_2O for 14 d (hydroponics)	0.1, 0.8, 1.5 mg Se L^{-1} as Na_2SeO_3 (14 days)	Se (0.8 mg L^{-1}) counteracted the negative effects of Sb on the cell membrane lipids & shoot biomass; reduced root growth parameters; SOD, APX, CAT play roles in rebalance in excess ROS resulting from exposure to Se and/or Sb (Feng et al. 2016)
Oryza sativa L. cv. Fengmeizhan	1, 2.2, 5, 7.8, 9 mg Sb L^{-1} as $KSbC_4H4O_7{\cdot}0.5H_2O$ for 14 days (hydroponics)	0.1, 0.3, 0.8, 1.3, 1.5 mg Se L^{-1} as Na_2SeO_3 (14 days)	Paddy rice can accumulate high concentrations of Se and Sb in its tissues (79 % in root cell wall); Se can reduce Sb toxicity *via* regulating its subcellular distribution in which cell wall & cytosol fractions may act as vessels to sequestrate excess Se and Sb (Ding et al. 2015)
Oryza sativa L. cv. Fengmeizhan	1, 2.2, 5, 7.8, 9 mg Sb L^{-1} as $KSbC_4H4O_7{\cdot}0.5H_2O$ for 14 days (hydroponics)	0.1, 0.3, 0.8, 1.3, 1.5 mg Se L^{-1} as Na_2SeO_3 (14 days)	Se-mediated alleviation of Sb toxicity could be closely connected with the direct inhibition of Sb uptake and the uptake regulation of some essential elements, such as Ca, Cu, K, Mg and Zn. Sb higher than 7.8 mg L^{-1} appeared to have antagonistic effects on the uptake of these elements (Feng et al. 2013b)
Oryza sativa L., cv. Weiyou 402	5 mg Sb L^{-1} as $KSbC_4H4O_7{\cdot}0.5H_2O$ for 14 days (hydroponics)	0.1, 1, 5 mg Se L^{-1} as Na_2SeO_3 (14 days)	Se (1–5 mg L^{-1}) could alleviate Sb toxicity (5 mg L^{-1}) in paddy rice through two effects as antagonism and antioxidation; decrease in MDA content and increase in biomass of plant (Feng et al. 2011)
Arsenic (As)			
Nicotiana tabacum L. var K326	1, 5 mg L^{-1} as $Na_3AsO_4.12H_2O$(hydroponics)	0.1, 1, 5 mg L^{-1} as Na_2SeO_3 (14 days)	Low Se dose (0.1 mg L^{-1}) alleviated of the toxicity of high As dose (5 mg L^{-1}); the addition of As counteracted the toxicity of high Se dose of 5 mg L^{-1} (Han et al. 2015)
Oryza sativa L. cv. Masina research-1	5 µg ml^{-1} as NaH_2AsO_4 (hydroponics)	0.5, 1, 2 µg ml^{-1} as Na_2SeO_3 (7 days)	Higher antioxidant enzymes (CAT, SOD, GST, POD, GR, AO) in As + Se + P along with lower level of H_2O_2, maximum reduction of As toxicity was achieved with combined application of 1 µg Se ml^{-1} and 10 µg PO_4^{-3} ml^{-1} (Kumar et al. 2015)
Oryza sativa L. var. PB-1	150 µM As as $NaAsO_2$ (hydroponics)	20 µM Se as Na_2SeO_4 (12 days)	Co-application of Se and auxin (3 µM as IAA) improved growth of rice seedlings, level of stress indicators, (chlorophyll, protein, MDA) and modulators (cysteine, proline) as compared the individual treatment of As (Pandey and Gupta 2015)
Oryza sativa L. cv. Jiahua 1	1 µM As as $NaAsO_2$ and $NaAsO_4{\cdot}12H_2$ (pot exper.)	1 µM as Na_2SeO_3 and Na_2SeO_4	Se supply decreases translocation of As from roots to shoots; play antagonistic role in As translocation from roots to shoots, due to As ligands such as PCs and GSH in roots, which sequestrate As into vacuoles of roots (Hu et al. 2014b)
Oryza sativa L.	25 µM As as Na_2HAsO_2 (hydroponics)	5, 10, 25, 50 µM Se as Na_2SeO_3 (7 days)	Se ameliorates induced oxidative stress through modulation of antioxidant enzymes (APX, CAT, GPx), thiols; modulate thiol metabolism enzymes including γ-ECS, GST and PCS (Kumar et al. 2014)
Oryza sativa L. cv. Prabhat	4 µg ml^{-1} As as $NaAsO_2$ (hydroponics)	0.75, 1.5 mg ml^{-1} as Na_2SeO_3 (7 days)	Co- application of P (5 mg ml^{-1}) and Se (0.75 mg ml^{-1}) provides maximum amelioration of As (4 µg ml^{-1}) toxicity in rice seedlings achieving a higher SOD, APX, POD activities in these previous Se, P and As doses (Kumar et al. 2013)
Phaseolus aureus Roxb.	2.5, 5, 10 µM As (hydroponics)	2.5, 5 µM Se (10 days)	Se antagonizes toxic As on mungbean by restricting its uptake and enhancing the antioxidation (SOD, CAT, APX, GR as well as AsA, GSH), detoxification by increasing MTs, thiols, GST activity in Se-treated plants (Malik et al. 2012)

	Cadmium (Cd)		
Triticum aestivum cv. WH 711	200 mg Cd kg^{-1} as $CdCl_2$ (pot exper.)	2 mg Se kg^{-1} as $Na_2SeO_3 \cdot 5H_2O$ (15 days)	Application of Se or sulfur (200 mg S kg^{-1}) alleviated Cd-induced oxidative stress by increasing proline, GR, GPX, GK activities; decreased proline oxidase activity and ethylene level; improved photosynthesis and growth (Iqbal et al. 2015b)
Brassica rapa ssp. rapa	100 µM Cd as $CdCl_2$ (tray experiments)	25 µM Se as SeO_2 selenium dioxide (7 days)	Turnip plants treated with Se and Cd showed significant induction of genes related to glucosinolate, phenolic, carotenoid biosynthesis; SeO_2- and putrescine (100 µM)-treated plants had lower H_2O_2 content (Thiruvengadam and Chung 2015)
Helianthus annuus	20 µM as $CdCl_2$ (hydroponics)	Seeds soaking: 5, 10, 20 µM Se as Na_2SeO_4 10 H_2O (24 h)	Se-pretreatment alleviated oxidative alteration generated by Cd in sunflower roots, lowered H_2O_2, PCO and MDA content. Se enhanced the activities of CAT, APX, GPx, but lowered that of SOD in the root exposed Cd (Issam et al. 2015)
Nicotiana tabacum L.	50 µM Cd for 7 days (hydroponics)	3 µM Se (7 days)	Se elevated Cd-depressed activities of SOD, POD, CAT, APX, GPx, GR as well as Pn, Gs and Tr content. Se counteracted Cd-induced alterations: increasing content of Zn and Ca whereas reducing Mg content (Liu et al. 2015a)
Boehmeria nivea L. Gaud.	5 mg L^{-1} Cd as $CdCl_2$ (Hydroponics)	1 µmol L^{-1} as Na_2SeO_3 (7 d) beside 1 mmol Si L^{-1}	Application of Se and/or silicon ameliorated Cd toxicity *via* stimulating the activities of antioxidant system (SOD, POD, APX, GR, thiols, GSH, vitamin E) resulting in decrease of MDA, H_2O_2 in ramie leaves (Tang et al. 2015)
Cucumis sativus L. cv. Polan F1	25, 50 µM Cd as $CdCl_2 \cdot 2.5H_2O$ (14 d) (hydroponics)	5, 10 µM Se as Na_2SeO_4 (14 d)	Se protects cucumber against Cd toxicity; partially alleviate its destructive physiological effects on plant; reducing Cd accumulation in roots; positive effects of Se on cell membrane stability in Cd-exposed plants, reduces PCs, GSH, MDA, Chl a,b, carotenoids (Hawrylak-Nowak et al. 2014)
Oryza sativa var. Shuang-you 998	1, 4, 12 mg Cd L^{-1} for 14 d (pot exper.)	0.2, 0.8 mg Se L^{-1} as Na_2SeO_3 (14 d)	Several Se-mediated mechanisms for mitigation of Cd toxicity: increase in the proportion of coarse roots to reduce Cd uptake as well as activation of antioxidative enzymes including SOD, APX, CAT, POD, GPx (Ding et al. 2014)
Oryza sativa L. cultivar Jiahua 1	0.22, 1.03 and 98.1 mg kg^{-1} of Se, Cd and Pb in soil used (pots)	0.5, 1 mg Se kg^{-1} as Na_2SeO_3 (14 d)	Se can mitigate of heavy metal including Cd and Pb accumulation in rice; decrease metal bioavailability in soil; it is an effective and feasible method to enrich Se; reduce Cd levels in brown rice (Hu et al. 2014a)
	Chromium (Cr)		
Brassica campestris L. sp. Pekinensis	Chromium: 1 mg L^{-1} Cr as $K_2Cr_2O_7$ (hydroponics)	Selenium: 0.1 mg L^{-1} Se as Na_2SeO_3 (30 days)	Se can alleviate Cr toxicity in cabbage leaves through this mechanism: reducing of free radicals and lipid peroxides; activating the antioxidant enzymes including SOD and POD; removing Cr from metabolically active cellular sites; Se altered subcellular distribution of Cr which transported from mitochondria, nucleus and the cell-wall material to the soluble fraction and chloroplasts (Qing et al. 2015)
Lead (Pb)			
Coleus Blumei Benth.	Lead: 1 mM Pb as $Pb(NO_3)_2$ (pot and hydroponic experiments)	Selenium: 0.1, 0.5, 1, 2.5, 5 mM Se as Na_2SeO_3 (21 days)	Se enhances biomass allocation and Pb distribution in different plant organs; decreases SOD and POD activities in roots; inhibits lipid peroxidation *via* increasing GSH levels; root CAT and GPx activities increases with Se concentration; Coleus plants can be used in phytoremediation of aquatic systems contaminated with Pb in presence of 1 mg Se kg^{-1}; GSH content increased up to a concentration of 2.5 mM Se and then decreased (Yuan et al. 2013a, b)
Vicia faba L. minor cv. Nadwiślański	Lead: 50 µM Pb as $Pb(NO_3)_2$ (hydroponics)	Selenium: 1.5, 6 µM as Na_2SeO_3 (14 days)	Se at 1.5 µM alleviates Pb toxicity by decreasing ROS production in the apical parts of roots, increasing the T-SH content and GPOX activity, whereas at 6 µM intensifies MDA and T-SH accumulation and GPOX and GSH-Px activity in Pb-treated plant roots (Mroczek-Zdyrska and Wójcik 2012)
	Mercury (Hg)		
Oryza sativa L.	236 and 0.69 mg kg^{-1} of Hg, Se content in soil used (field)	0.01, 0.1, 0.5, 1, 5 µg Se mL^{-1} as Na_2SeO_3	Se at 0.5 µg ml^{-1} level is an efficient way to reduce Hg accumulation in rice; increase rice yield and quality, thereafter to protect the health of the rice-dependent populations in Hg contaminated area (Li et al. 2015)

Previous studies discussed the interaction between Se with other elements included 2 or maximum 3 of the elements mentioned above (e.g. Pickering 2016). Concerning this interaction between Se and these previous nutrients (Table 3), some publications have been issued including relationship with S (White *et al.,* 2004; Galeas *et al.,* 2007; White *et al.,* 2007; Pilon-Smits and Quinn 2010; Cabannes *et al.,* 2011; Hawrylak-Nowak 2013; Cappa *et al.* 2014; Chao *et al.,* 2014; Khan and Hell 2014; Schiavon *et al.,* 2015; Liu *et al.,* 2015b; Qin *et al.,* 2016), iodine (Zhu *et al.,* 2004; Gómez-Jacinto *et al.,* 2012; Galinha *et al.,* 2013; Smolen *et al.,* 2014), Zn (Germ *et al.,* 2013; Mao *et al.,* 2015), Cu (Landberg and Greger 1994; Hu *et al.,* 2013; Longchamp *et al.,* 2015), as well as the multiple interaction for both Se, S, Mo (Zhang *et al.,* 2012; Harris *et al.,* 2014; DeTar *et al.,* 2015), Se, Zn and iodine (Bevis 2015).

In general, Se and these nutrients have a similar trend in connection with the uptake and its transporters, the biological functions in plants (as a component of some enzymes) and antagonism behavior. For example, selenate, sulfate, molybdate and iodate are similar oxyanion forms that plants uptake from soil as well as all can make use of the same sulfate transporters (Shinmachi *et al.,* 2010; DeTar *et al.,* 2015). Increased Se levels in plants suppress the concentrations of N, P, and S, as well as several amino acids, thus high Se concentrations inhibit the absorption of metals, mainly Mn, Zn, Cu and Cd (Kabata-Pendias 2011).

Although Se and its essentiality are established for human and animals as well as lower plants, nano-Se and Se are required much more evidence for this essentialty in higher plants. The role of Se under different biotic and abiotic stresses has been recorded in case of animals and somehow higher plants, whereas nano-Se is still in needing for more researches to cover this area. The documented behavior of higher plants under Se and abiotic stresses includes the role of Se in enhancing plant defense system including enzymes (CAT, GPx, SOD, GR, DHAR, etc.) and nonenzymes (GSH, GSSG, AsA, etc.). The roles of Se in protecting photosystems from generation/ scavenging of reactive oxygen species are also well known. This role of nano-Se for higher plants needs much more studies comparing with this effect on animals. The interaction between Se and S can be found in several publications for many plants, whereas this interaction between Se and some nutrients including Cu, Mo, Zn and iodine is not fully clear and this issue needed to be explored.

Acknowledgments: Authors thank the outstanding contribution of STDF research teams (Science and Technology Development Fund, Egypt) and MBMF/DLR (the Federal Ministry of Education and Research of the Federal Republic of Germany), (Project ID 5310) for their help. Great support from this German-Egyptian Research Fund (GERF) is gratefully acknowledged.

References

Abd-Allah, S. and Hashem, K.S. (2015) Selenium nanoparticles increase the testicular antioxidant activity and spermatogenesis in male rats as compared to ordinary selenium. ***International Journal of Advanced Research*****, 3 (1),792-802. ISSN 2320-5407.**

Ahmad, R., Waraich, E. A., Nawaz, F., Ashraf,M. Y. and Khalidd, M. (2015) Selenium (Se)improves drought tolerance in crop plants – amyth or fact? *J. Sci Food Agric,* DOI 10.1002/jsfa.7231.

Akladious, S. A. (2012) Influence of different soaking times with selenium on growth, metabolic activities of wheat seedlings under low temperature stress. *African Journal of Biotechnology* **11**(82),14792-14804. DOI: 10.5897/AJB12.2140 .

Alford, É. R., Pilon-Smits, E. A. H., Fakra,S. C. and Paschke, M.W. (2012) Selenium hyperaccumulation by Astragalus (Fabaceae) does not inhibit root nodule symbiosis. *American Journal of Botany* **99**(12), 1930–1941. Doi:10.3732/ajb.1200124.

Bachiega, P., Salgado, J. M. ,de Carvalho, A. L. Ruiz, T.G., Schwarz, K., Tezotto, T. and Morzelle,M. C. (2016) Antioxidant and antiproliferative activities in different maturation stages of broccoli (Brassica oleracea Italica) biofortified withselenium. *Food Chemistry*, **190,**771-776.

Bañuelos, G.S., Fakra, S.C., Walse, S.S., Marcus, M.A., In Yang, S ., Pickering,I. J., Pilon-Smits, E. A.H. and Freeman,J.L. (2011) Selenium accumulation, distribution, and speciation in spineless prickly pear cactus: a drought-and salt-tolerant, selenium-enriched nutraceutical fruit crop for biofortified foods. *Plant Physiology* **155**(1), 315-327. DOI: http://dx.doi.org/10.1104/pp.110.162867.

Bao, Z. Y., Tian, H., You,Y. H. and Wei, C. H. (2016)

High selenium content reduces cadmium uptake in Cardamine hupingshanesis (Brassicaceae). In: Global advances in selenium research from theory to application. G. S. Bañuelos, Z.-Q. Lin, L. R. G. Guilherme and A. R. dos Reis (Eds.), *Proceedings of the 4th International Conference on Selenium in the Environment and human health, Sao Paulo,* Brazil, 18–21 October 2015. CRC, Taylor & Francis Group, London, UK, pp: 139 – 140.

Barrientos, E. Y., Flores, C. R., Wrobel, K. and Wrobel, K. (2012) Impact of cadmium and selenium exposure on trace elements, fatty acids and oxidative stress in Lepidium sativum. *J. Mex. Chem. Soc.* **56**(1), 3-9. ISSN 1870-249X .

Bevis L.E.M. (2015) Soil- to- human mineral transmission with an emphasis on Zinc, Selenium, and Iodine. *Springer Science Reviews* **3,**77–96. DOI 10.1007/s40362-014-0026-y.

Bhattacharjee, A., Basu, A., Ghosh,P., Biswas, J. and Bhattacharya, S. (2014) Protective effect of selenium nanoparticle against cyclophosphamide induced hepatotoxicity and genotoxicity in Swiss albino mice. *Journal of Biomaterials Applications* **29**(2), 303–317. DOI: 10.1177/0885328214523323.

Boostani, A., Sadeghi A.A., Mousavi, S.N., Chamani, M. and Kashan, N. (2015) Effects of organic, inorganic, and nano-Se on growth performance, antioxidant capacity, cellular and humoral immune responses in broiler chickens exposed to oxidative stress. *Livestock Science*, http://dx.doi.org/10.1016/j.livsci.2015.05.004.

Cabannes, E., Buchner, P., Broadley, M.R., Hawkesford, M.J. (2011) A comparison of sulfate and selenium accumulation in relation to the expression of sulfate transporter gene in Astragalus species. *Plant Physiol.* **157**(4), 2227-39. Doi: 10.1104/pp.111.183897.

Cai, S. J., Wu, C.X., Gong, L. M., Song, T., Wu,H. and Zhang, L.Y. (2012) Effects of nano-selenium on performance, meat quality, immune function, oxidation resistance, and tissue selenium content in broilers. *Poultry Science* **91,** 2532–2539. http://dx.doi.org/10.3382/ps.2012-02160.

Cappa, J.J., Cappa, P.J., El Mehdawi, A.F., McAleer, J.M., Simmons, M.P., Pilon-Smits, E.A. (2014) Characterization of selenium and sulfur accumulation across the genus Stanleya (Brassicaceae): A field survey and common-garden experiment. *Am J. Bot.* **101**(5), 830-839. Doi:10.3732/ajb.1400041.

Cartes, P., Gianfreda, L., Paredes, C. and Mora,M. L. (2010) The Effect of seed pelletization with selenite on the yield and selenium uptake of ryegrass cultivars. *19th World Congress of Soil Science, Soil Solutions for a Changing World 1 – 6 August 2010, Brisbane,* Australia. Published on CDROM. Pp: 310 – 313.

Cartes, P., L. Gianfreda, C. Paredes and M. L. Mora (2011) Selenium uptake and its antioxidant role in ryegrass cultivars as affected by selenite seed pelletization. *J.Soil. Sci. Plant Nutr.* **11,** 1–14.

Chao, D.Y., Baraniecka, J., Danku, A., Koprivova, B., Lahner, H. Luo, E., Yakubova, B., Dilkes, S., Kopriva and Salt, D. E. (2014) Variation in sulfur and selenium accumulation: Is controlled by naturally occurring isoforms of the key sulfur assimilation enzyme ADENOSINE 5′-PHOSPHOSULFATE REDUCTASE2 across the Arabidopsis species Range. *Plant Physiol*. **166**(3),1593–1608. Doi: 10.1104/pp.114.247825.

Chu, J., Yao, X. and Zhang, X. (2010) Responses of wheat seedlings to exogenous selenium supply under cold stress. *Biological Trace Element Research* **136** (3), 355-363. DOI: 10.1007/s12011-009-8542-3.

DeTara, R. A., Alford,É. R. and Pilon-Smits, E. A. H. (2015) Molybdenum accumulation, tolerance and molybdenum–selenium–sulfur interactions in Astragalus selenium hyperaccumulator and nonaccumulator species. *Journal of Plant Physiology* **183,** 32–40. http://dx.doi.org/10.1016/j.jplph.2015.05.009.

Diao, M., Ma, L., Wang,J., Cui, J., Fu, A. and Liu, H.Y. (2014) Selenium promotes the growth and photosynthesis of tomato seedlings under salt stress by enhancing chloroplast antioxidant defense system. *Journal of Plant Growth Regulation* **33** (3), 671-682. DOI: 10.1007/s00344-014-9416-2.

Ding Y., Wang, R., Guo, J., Wu, F., Xu,Y. and Feng, R. (2015) The effect of selenium on the subcellular distribution of antimony to regulate the toxicity of antimony in paddy rice. *Environ Sci Pollut Res,* DOI 10.1007/s11356-014-3865-9.

Ding, Y., Feng, R., Wang,R., Guo,J. and Zheng, X. (2014) A dual effect of Se on Cd toxicity: evidence from plant growth, root morphology and responses of the antioxidative systems of paddy rice. *Plant and soil* **375**,289–301. DOI 10.1007/s11104-013-1966-8.

Djanaguiraman, D., Devi, D.D., Shanker,A.K., Annie Sheeba, J. and Bangarusamy,U. (2005) Impact of selenium spray on monocarpic senescence of soybean (Glycine Max L.). *Plant and Soil* **272** (1),77-86. DOI: 10.1007/s11104-004-4039-1.

Djanaguiraman, M., Durga, D., Devi, Arun, K. Shanker, J., Annie Sheeba and Bangarusamy,U. (2004) Impact of selenium spray on monocarpic senescence of soybean (*Glycine Max* L.). *Food, Agriculture & Environment* **2**(2), 44-47.

Djanaguiraman, M., Prasad, P.V.V., Seppänen, M. (2010) Selenium protects sorghum leaves from oxidative damage under high temperature stress by enhanc-ing antioxidant defense system. *Plant Physiology and Biochemistry* **48** (12), 999–1007.

Domokos-Szabolcsy, E. (2011) Biological effect and fortification possibilities of inorganic selenium forms in higher plants *PhD dissertation.* Debrecen Uni.

Domokos-Szabolcsy, E., Marton, L., Sztrik, B., Babka, J., Prokisch and Fari, M. (2012) Accumulation of red elemental selenium nanoparticles and their biological effects in Nicotinia tabacum. *Plant Growth Regul,* **68,** 525–531.

Domokos-Szabolcsy, E., N. A., Alladalla, T., Alshaal, A., Sztrik, L., Mártonand El-Ramady,H. (2014) In vitro comparative study of two Arundo donax L. ecotypes' selenium tolerance. *International Journal of Horticultural Science*, **20** (3–4), 119–122. ISSN 1585-0404.

Durán, P., Acuña, J.J., Gianfreda, L., Azcón, R., Funes-Collado, V. and Mora, M. L. (2015) Endophytic selenobacteria as new inocula for selenium biofortification. *Applied Soil Ecology* **96,** 319–326. http:// dx.doi.org/ 10.1016/j.apsoil.2015.08.016.

Dwivedi, S., Alkhedhairy, A. A., Ahamed,M. and Musarrat, J. (2013) Biomimetic synthesis of selenium nanospheres by bacterial strain JS-11 and its role as a biosensor for nanotoxicity assessment: a novel Se-bioassay. *PLoS One* **8,** 1–10.

Elguera, J. C. T., Barrientos, E. Y., Wrobel, K. and Wrobel, K. (2013) Effect of cadmium (Cd(II)), selenium (Se(IV)) and their mixtures on phenolic compounds and antioxidant capacity in Lepidium sativum. *Acta Physiol Plant* **35**,431–441. DOI 10.1007/s11738-012-1086-8.

El Mehdawi, A.F. and Pilon-Smits, E.A. (2012) Ecological aspects of plant selenium hyperaccumulation. *Plant Biol.* **14**(1), 1-10. Doi: 10.1111/j.1438-8677.2011.00535.x.

El Mehdawi, A. F., Paschke,M. W. and Pilon-Smits, E. A. H. (2015) Symphyotrichum ericoides populations from seleniferous and nonseleniferous soil display striking variation in selenium accumulation. *New Phytologist,* **206,** 231–242. Doi: 10.1111/nph.13164 .

El-Ramady, H., Domokos-Szabolcsy, É., Abdalla, N.A., Alshaal,T.A., Shalaby, T.A., Sztrik, A., prokisch, J., Fári, M. (2014a) Selenium and nano-selenium in agroecosystems. *Environmental Chemistry Letters,* **12** (4), 495-510. DOI 10.1007/s10311-014-0476-0.

El-Ramady, H., Abdalla, T. A., Alshaal, N. , Elhawat, É., Domokos-Szabolcsy, J., Prokisch, A., Sztrik and Fári, M. (2014b) Nano-selenium: from in vitro to micro farm experiments. *The International Conference "Biogeochemical Processes At Air-Soil-Water Interfaces And Environmental Protection" For The European Society For Soil Conservation, Imola–Ravenna,* Italy 23-26 June 2014. DOI: 10.13140/2.1.2260.4481.

El-Ramady, H., Abdalla, N., Alshaal, T., El-Henawy, A. Faizy, S. E.-D. A., Shams, M. S., Shalaby,T. Y., Bayoumi, N., Elhawat, S.. Shehata, A., Sztrik, J.. Prokisch, M., Fári, E. Pilon-Smits,A. and Domokos-Szabolcsy, É. (2015a) Selenium and its role in higher plants. In: E. Lichtfouse et al. (Eds.), *Environmental Chemistry for a Sustainable World* Vol. 7, Springer Science + Business Media B.V. DOI 10.1007/978-3-319-19276-5_6, pp: 235 – 296.

El-Ramady, H., Domokos-Szabolcsy, É., Shalaby,T. A., Prokisch,J. and Fári,M. (2015b) Selenium in agriculture: water, air, soil, plants, food, animals and nanoselenium. In: E. Lichtfouse (Ed.), *Environmental Chemistry for a Sustainable World* Vol. 5 (CO2 sequestration, biofuels and depollution), pp: 153 – 232. DOI 10.1007/978-3-319-11906-9_5. Springer Berlin.

El-Ramady, H., Abdalla, N., Taha, H. S., Alshaal,T., El-Henawy, A., Faizy, S. E.D. A., Shams, M. S., Youssef, S. M., Shalaby, T., Bayoumi, Y., Elhawat, S., Shehata, N., Sztrik, A., Prokisch, J. Fári, M., Domokos-Szabolcsy, É., Pilon-Smits,E. A., Selmar,D. Haneklaus,D. and Schnug,E. (2015c) Selenium and nano-selenium in plant nutrition. *Environ Chem Lett,* DOI: 10.1007/s10311-015-0535-1.

El-Ramady, H., Abdalla, N., Alshaal, T., Domokos-Szabolcsy, É., Elhawat, N., Prokisch, J., Sztrik A, Fári, M., El-Marsafawy, S., Shams, M.S. (2015d) Selenium in soils under climate change, implication for human health. *Environmental Chemistry Letters,* **13** (1), 1–19. DOI 10.1007/s10311-014-0480-4.

El-Ramady, H., N. Abdalla, T. Alshaal, A. S. Elhenawy, M. S. Shams, S. E.-D. A. Faizy, E. B. Belal, S. A. Shehata, M. I. Ragab, M. M. Amer, M. Fari, A. Sztrik, J. Prokisch, D. Selmar, E. Schnug, E. A. H. Pilon-Smits, S. El-Marsafawy, M. and Domokos-Szabolcsy,E. (2015e) Giant reed for selenium phytoremediation under changing climate. *Environ Chem Lett,* DOI 10.1007/s10311-015-0523-5.

El-Ramady H., Alshaal, T., Abdalla, N., Prokisch, J., Sztrik, A., Fári, M. and Domokos-Szabolcsy,É. (2016) Selenium and nano-selenium biofortified sprouts using micro-farm systems. In: Global advances in selenium research from theory to application. G. S. Bañuelos, Z.-Q. Lin, L. R. G. Guilherme and A. R. dos Reis (Eds.), *Proceedings Of The 4Th International Conference On Selenium In The Environment And Human Health, Sao Paulo,* Brazil, 18–21 October 2015. CRC, Taylor & Francis Group, London, UK, pp: 189 – 190.

El-Shalakany, W.A., Shatlah, M.A., Atteia,M.H, Sror, H.A.M. (2010) Selenium induces antioxidant defensive enzymes and promotes tolerance against salinity stress in cucumber seedlings (Cucumis sativus). *Arab Univ J. Agric .Sci.* **18,**65–76.

Emam, M. M., Hemmat, E. Khattab, Nesma, M. Helal, Abdelsalam Deraz, E. (2014) Effect of selenium and silicon on yield quality of rice plant grown under drought stress. *Australian Journal of Crop Science* **8**, 596–605.

Feng, R., Wei, C. and Tu,S. (2013a) The roles of selenium in protecting plants against abiotic stresses. *Environmental and Experimental Botany* **87**,58–68. doi:10.1016/j.envexpbot.2012.09.002.

Feng, R., Wei, C.,Tu, S. and Liu, Z. (2013b) Interactive effects of selenium and antimony on the uptake of selenium, antimony and essential elements in paddy-rice. *Plant and Soil* **365** (1-2), 375-386. DOI: 10.1007/s11104-012-1399-9.

Feng, R., Wei, C., Tu, S., Tang,S. and Wu, F. (2011) Detoxification of antimony by selenium and their interaction in paddy rice under hydroponic conditions. *Microchemical Journal,* **97** (1),57–61. DOI:10.1016/j.microc.2010.06.003

Feng, R., Wei, C., Tu, S., Ding, Y. and Song, Z. (2013c) A dual role of se on cd toxicity: evidences from the uptake of cd and some essential elements and the growth responses in paddy rice. *Biol Trace Elem Res* **151,**113–121. DOI 10.1007/s12011-012-9532-4.

Feng R., Liao, G., Guo, J., Wang, R., Xu, Y ., Ding, Y., Mo, L., Fan, Z. and Li, N. (2016) Responses of root growth and antioxidative systems of paddy rice exposed to antimony and selenium. *Environmental and Experimental Botany,* **122**, 29-38.

Fuge, R. (2013) Soils and iodine deficiency. In: O. Selinus *et al.,* (Eds.), *Essentials of Medical Geology: Revised Edition,* DOI 10.1007/978-94-007-4375-5_17, pp: 417 – 432. Springer Science + Business Media Dordrecht, NY, USA

Gajewska, E., Drobik, D., Wielanek, M ., Sekulska-Nalewajko, J., Gocławski, J. Mazur, J. and Skłodowska, M. (2013). Alleviation of nickel toxicity in wheat (*Triticum aestivum* L.) seedlings by selenium supplementation. *Biological Lett.* **50**(2), 63–76. DOI: 10.2478/biolet-2013-0008

Galeas, M. L., Zhang, L. H. , Freeman, J. L. , Wegner, M. and Pilon-Smits , E. A. H. (2007) Seasonal fluctuations of selenium and sulfur accumulation in selenium hyperaccumulators and related non-accumulators. *New Phytologist,* **173,** 517–525.

Galinha C., do, M., Freitas, C. Pacheco, A. M. G., Coutinho, J., Macas,B. and Almeida,A.S. (2013) Selenium supplementation of Portuguese wheat cultivars through foliar treatment in actual field conditions. *J. Radioanal Nucl Chem* **297,** 227–231. DOI 10.1007/s10967-012-2372-z

Germ, M.,Stibilj, V., Osvald, J. and Kreft, I. (2007) Effect of selenium foliar application on chicory (*Cichorium intybus* L.). *J. Agric. Food Chem.,* **55,** 795-798.

Germ, M., Pongrac, P., Regvar,M., Vogel-Mikuš, K., Stibilj,V., Jaćimović, R., Kref, I. (2013) Impact of double Zn and Se biofortification of wheat plants on the element concentrations in the grain. *Plant Soil Environ,* **59** (7), 316–321.

Ghezzi J., Karathanasis, A., Matocha, C., Unrine , J. and Thompson, Y. (2014) Competitive Sorption Behavior of Arsenic, Selenium, Copper and Lead by Soil and Biosolid Nano- and Macro-Colloid Particles. *Open Journal of Soil Science,* **4,** 293-304. http://dx.doi.org/10.4236/ojss.2014.49031.

Gómez-Jacinto, V., García-Barrera,T., Garbayo-Nores, I., Vilchez-Lobato, C. and Gómez-Ariza, J.L. (2012) Metal-metabolomics of microalga growing in selenium- and iodine-enriched media. *Chemical Papers* **66** (9), 821–828. DOI: 10.2478/s11696- 012-0186-7.

Gu, A. Q., Luo,Y. Y., Tian, H., Bao, Z. Y., Wei,C. H. and Chen, X. L. (2016) Selenium accumulation and its effects on heavy metal elements in garlic. In: Global advances in selenium research from theory to application. G. S. Bañuelos, Z.Q. Lin, L. R. G. Guilherme and A. R. dos Reis (Eds.), *Proceedings Of The 4Th International Conference On Selenium In The Environment And Human Health, Sao Paulo,* Brazil, 18–21 October 2015. CRC, T*aylor & Francis Group, London*, UK, pp: 141 – 142.

Habibi G. (2013) Effect of drought stress and selenium spraying on photosynthesis and antioxidant activity of spring barley. *Acta Agriculturae Slovenica,* 101 – **1,** 31 – 39. DOI: 10.2478/acas-2013-0004.

Haghighi, M., Abolghasemi, R. and Teixeira da Silva,J.A. (2014) Low and high temperature stress affect the growth characteristics of tomato in hydroponic culture with Se and nano-Se amendment. *Scientia Horticulturae* **178,** 231–240. Doi:10.1016/j. scienta.2014.09.006.

Hajiboland, R. (2012) Effect of micronutrient deficiencies on plants stress responses. In: P. Ahmad and M. N. V. Prasad (Eds.), A*biotic Stress Responses in Plants: Metabolism, Productivity and Sustainability,* DOI 10.1007/978-1-4614-0634-1_16, Springer Science + Business Media, LLC, pp: 283 – 329.

Hajiboland, R., Sadeghzadeh,N. and Sadeghzadeh,B. (2014) Effect of Se application on photosynthesis, osmolytes and water relations in two durum wheat (*Triticum durum* L.) genotypes under drought stress. *Acta Agriculturae Slovenica,* 103 – **2,**167 – 179. DOI: 10.14720/aas.2014.103.2.2.

Hajiboland, R., Rahmat, S. Aliasgharzad, N. and Hartikainen, H. (2015) Selenium-induced enhancement in carbohydrate metabolism in nodulated alfalfa (*Medicago sativa* L.) as related to the glutathione redox state, *Soil Science and Plant Nutrition,* DOI: 10.1080/00380768.2015.1032181.

Han, D., Xiong, S. Tu,S.Liu, J. and Chen,C. (2015) Interactive effects of selenium and arsenic on growth, antioxidant system, arsenic and selenium species of Nicotiana tabacum L. *Environmental and Experimental Botany* **117,**12–19. Doi:10.1016/j. envexpbot.2015.04.008.

Handa, N., Bhardwaj, R., Kaur,H., Kapoor, D., Rattan, A., Kaur, S., Thukral, A. K., Kaur, S., Arora, S. and Kapoor,N. (2016) Selenium: an antioxidative protectant in plants under stress. In: P. Ahmad (Ed.), *Plant Metal Interaction: Emerging Remediation Techniques.* Elsevier, pp: 179-207. ISBN :9780128031582.

Harris J., Schneberg,K. A. and Pilon Smits,E. A. H. (2014) Sulfur–selenium–molybdenum interactions distinguish selenium hyperaccumulator Stanleya pinnata from non hyperaccumulator Brassica juncea (Brassicaceae). *Planta* **239,** 479–491. DOI 10.1007/ s00425-013-1996-8.

Hasanuzzaman, M. and Fujita, M. (2011) Selenium pretreatment upregulates the antioxidant defense and methylglyoxal detoxification system and confers enhanced tolerance to drought stress in rapeseed seedlings. *Biol Trace Elem Res.* **143,**1758–1776. Doi: 10.1007/s12011-011-8998-9.

Hasanuzzaman, M., Hossain, M.A., Fujita, M. (2010) Selenium in higher plants: physiological role, antioxidant metabolism and abiotic stress tolerance. *J. Plant Sci* **5,** 354–375. DOI: 10.3923/jps.2010.354.375.

Hasanuzzaman, M., Nahar,K. and Fujita, M. (2013)Plant response to salt stress and role of exogenous protectants to mitigate salt-induced damages. In: P. Ahmad *et al.* (Eds.), *Ecophysiology And Responses Of Plants Under Salt Stress,* pp: 25 – 87. DOI 10.1007/978-1-4614-4747-4_2, Springer Science + Business Media, LLC.

Hasanuzzaman, M., Nahar,K. Md. Alam, M. and Fujita, M. (2014) Modulation of antioxidant machinery and the methylglyoxal detoxification system in selenium-supplemented Brassica napus seedlings confers tolerance to high temperature stress. *Biol Trace Elem Res* **161,** 297–307. DOI 10.1007/s12011-014-0120-7.

Hashem, H. A., Hassanein,R. A., Bekheta, M. A. and El-Kady,F. A. (2013) Protcetive role of selenium in canola (*Brassica napus* L.) plant subjected to salt stress. *Egypt. J. Exp. Biol. (Bot.).* **9**(2),199-211.

Hassanin K. M. A., Abd El-Kawi, S. H. and Hashem, K. S. (2013) The prospective protective effect of selenium nanoparticles against chromium-induced oxidative and cellular damage in rat thyroid. *International Journal of Nanomedicine* **8,** 1713–1720. DOI: http://dx.doi. org/10.2147/IJN.S42736.

Hawrylak, B., Matraszek, R. and Szymanska, M. (2007) Reaction of lettuce (*Lactuca sativa* L.) to selenium in nutrient solution contaminated with nickel. *Veg. Crops Res. Bull.,* **67**, 63-70.

Hawrylak-Nowak B. (2013) Comparative effects of selenite and selenate on growth and selenium accumulation in lettuce plants under hydroponic conditions. *Plant Growth Regul* **70,**149–157. DOI 10.1007/s10725-013-9788-5.

Hawrylak-Nowak, B. (2009) Beneficial effects of exogenous selenium in cucumber seedlings subjected to salt stress. *Biol Trace Elem Res* **132**, 259–269.

Hawrylak-Nowak, B., Matraszek, R. and Szymańska, M. (2010) Selenium modifies the effect of short-term chilling stress on cucumber plants. *Biol Trace Elem Res.***138**(1-3), 307-15. Doi: 10.1007/s12011-010-8613-5.

Hawrylak-Nowak, B., Dresler, S. and Wójcikba, M. (2014) Selenium affects physiological parameters and phytochelatinsaccumulation in cucumber (*Cucumis sativus* L.) plants grownunder cadmium exposure. *Scientia Horticulturae* **172,** 10–18. http://dx.doi.org/10.1016/j.scienta.2014.03.040.

Hawrylak-Nowak B., Matraszek, R. and Pogorzelec, M. (2015)The dual effects of two inorganic selenium forms on the growth, selected physiological parameters and macronutrients accumulation in cucumber plants. *Acta Physiol Plant* **37,** 41. DOI: 10.1007/s11738-015-1788-9.

Hu B., Liang, D. Liu, J. and Xie, J. (2013) Ecotoxicological effects of copper and selenium combined pollution on soil enzyme activities in planted and unplanted soils. *Environ Toxicol Chem.* **32**(5), 1109-16. DOI: 10.1002/etc.2152.

Hu, C. H., Li, Y. L. ,Xiong, L. , Zhang, H. M. , Song,J. and Xia,M. S. (2012) Comparative effects of nano elemental selenium and sodium selenite on selenium retention in broiler chickens. *Animal Feed Science and Technology,* **177,** 204– 210.

Hu, Y., Norton, G. J., Duan, G., Huang, Y. and Liu, Y. (2014a) Effect of selenium fertilization on the accumulation of cadmium and lead in rice plants. *Plant and Soil* **384** (1-2), 131-140. DOI: 10.1007/s11104-014-2189-3.

Hu, Y., Duan, G.L., Huang,Y.Z., Liu, Y.X. and Sun, G.X (2014b) Interactive effects of different inorganic As and Se species on their uptake and translocation by rice (*Oryza sativa* L.) seedlings. *Environ Sci Pollut Res Int.* **21**(5), 3955-62. Doi: 10.1007/s11356-013-2321-6.

Ibrahim, H. M. (2014) Selenium pretreatment regulates the antioxidant defense system and reduces oxidative stress on drought-stressed wheat (*Triticum aestivum* L.) plants. *Asian J. of Plant Sci.* **13** (3), 120-128. DOI: 10.3923/ajps.2014.120.128

Iqbal, M., Hussain, I., Liaqat, H., Arslan, M., Ashraf, Rizwan Rasheed and Aziz Ur Rehman (2015a) Exogenously applied selenium reduces oxidative stress and induces heat tolerance in spring wheat. *Plant Physiology and Biochemistry* **94,**95-103. DOI:10.1016/j.plaphy.2015.05.012

Iqbal, M., R. Khan, F. Nazir, Asgher,M. Per, T. S. and Khan,N. A. (2015b) Selenium and sulfur influence ethylene formation and alleviate cadmium-induced oxidative Stress by improving proline and glutathione production in wheat. *Journal of Plant physiology* **173,** 9-18. DOI:10.1016/j.jplph.2014.09.011.

Issam, S., Wahbi, D. and Yacine, C. (2015) Selenium treatment alleviated oxidative alteration generated by cadmium in sunflower toots. *British Biotechnology Journal,* **5** (4),174-181. DOI: 10.9734/BBJ/2015/14802.

Jain, R., Verma, R., Singh, A., Chandra, A. and Solomon,S. (2015) Influence of selenium on metallothionein gene expression and physiological characteristics of sugarcane plants. *Plant Growth Regulation,* DOI: 10.1007/s10725-015-0042-1.

Jones, J.B. Jr. (2003) A*gronomic Handbook – Management Of Crops, Soils, And Their Fertility.* CRC Press, Boca Raton, FL.

Jones, J. B. Jr. (2005) *Hydroponics – A Practical Guide for the Soilless Grower.* 2nd Edition. CRC PRESS, Boca Raton London New York Washington, D.C.

Kabata-Pendias, A. and Mukherjee, A. B. (2007) *Trace Elements From Soil To Human.* Springer-Verlag Berlin Heidelberg, New York.

Kabata-Pendias, A. and Szteke, B. (2015) *Trace Elements In Abiotic And Biotic Environments. CRC Press Taylor & Francis Group, Boca Raton,* FL.

Kabata-Pendias, E. (2011) *Trace Elements In Soils And Plants.* 4th ed. Taylor and Francis Group, LLC. CRC

Press Taylor & Francis Group, Boca Raton, FL.

Kaur, N., Sharma, S., Kaur, S. and Nayyar, H. (2014) Selenium in agriculture: a nutrient or contaminant for crops?, *Archives of Agronomy and Soil Science,* **60** (12), 1593-1624. DOI: 10.1080/03650340.2014.918258.

Khan M. S. and Hell, R. (2014) Applied Cell Biology of Sulphur and Selenium in Plants. In: P. Nick and Z. Opatrny´ (Eds.), *Applied Plant Cell Biology, Plant Cell Monographs* **22,** DOI 10.1007/978-3-642-41787-0_8, Springer-Verlag Berlin Heidelberg, pp: 247 – 272.

Khan, K. U., Zuberi, A. , Jamil,Z., Sarwar,H., Nazir, S. and Fernandes, J. B. K. (2016) Health impact of dietry selenium nanoparticles on mahseer fish. In: Global advances in selenium research from theory to application. G. S. Bañuelos, Z.-Q. Lin, L. R. G. Guilherme and A. R. dos Reis (Eds.), *Proceedings of the 4th International Conference on Selenium in the Environment and Human Health, Sao Paulo,* Brazil, 18–21 October 2015. CRC, Taylor & Francis Group, London, UK, pp: 87 – 88.

Khattab, H.I., Emam, M.A., Emam, M.M., Helal, N.M. and Mohamed, M. R. (2014) Effect of selenium and silicon on transcription factors NAC5 and DREB2A involved in drought-responsive gene expression in rice. *Biologia Plantarum* **58** (2), 265-273. DOI: 10.1007/s10535-014-0391-z

Kirkby, E. (2012) Introduction, definition and classification of nutrients. In: Marschner's Mineral Nutrition of Higher Plants, *Petra Marschner* (Ed.) DOI:10.1016/B978-0-12-384905-2.00001-7, Elsevier Ltd., pp: 1 – 5.

Kojouri, G. A., Sadeghian, S., Mohebbi, A. and Dezfouli,M. R. M. (2012) The effects of oral consumption of selenium nanoparticles on chemotactic and respiratory burst activities of neutrophils in comparison with sodium selenite in sheep. *Biol Trace Elem Res.* **146**(2), 160–166. Doi: 10.1007/s12011-011-9241-4.

Kumar, A., Singh, R.P., Singh, P.K., Awasthi, S., Chakrabarty, D., Trivedi, P.K., Tripathi, R.D. (2014) Selenium ameliorates arsenic induced oxidative stress through modulation of antioxidant enzymes and thiols in rice (*Oryza sativa* L.). *Ecotoxicology,* **23**,1153-1163.

Kumar, N., Dubey, A.K., Jaiswal, P.K., Sahu, N., Behera, S., Tripathi, R.D. and Mallick, S. (2015) Selenite supplementation reduces arsenate uptake greater than phosphate but compromises the phosphate level and physiological performance in hydroponically grown *Oryza sativa* L. *Environ Toxicol Chem*. doi: 10.1002/etc.3171.

Kumar, N., Mallick, S., Yadava, R.N., Singh, A.P., Sinha, S. (2013) Co-application of selenite and phosphate reduces arsenite uptake in hydroponically grown rice seedlings: toxicity and defence mechanism. *Ecotoxicol. Environ. Saf.* **91,**171–179.

Kumar, B. S. and Priyadarsini,K. I. (2014) Selenium nutrition: How important is it? *Biomedicine & Preventive Nutrition* **4** (2), 333–341. doi:10.1016/j.bionut.2014.01.006.

Longchamp, M., Angeli, N., Castrec-Rouelle,M. (2015) Effects on the accumulation of calcium, magnesium, iron, manganese, copper and zinc of adding the two inorganic forms of selenium to solution cultures of Zea mays, *Plant Physiology et Biochemistry,* doi: 10.1016/j.plaphy.2015.11.013.

Landberg, T. and Greger,M. (1994) Influence of selenium on uptake and toxicity of copper and cadmium in pea (*Pisum sativum*) and wheat (*Triticum aestivum*). *Physiologia Plantarum* **90** (4), 637–644. DOI: 10.1111/j.1399-3054.1994.tb02518.x

Li, Y.F., Zhao,J., Li,Y., Li, H., Zhang, J., Li, B., Gao,Y., Chen,C., Luo,M., Huang, R. and Li,J. (2015) The concentration of selenium matters: a field study on mercury accumulation in rice by selenite treatment in qingzhen, Guizhou, China. *Plant and Soil* **391,**195–205. DOI 10.1007/s11104-015-2418-4.

Liu, W., Shang,S. Feng, X., Zhang, G. and Wu,F. (2015a) Modulation of exogenous selenium in cadmium-induced changes in antioxidative metabolism, cadmium uptake and photosynthetic performance in the 2 tobacco genotypes differing in cadmium tolerance. *Environ Toxicol Chem.* **34**(1), 92-9. Doi: 10.1002/etc.2760.

Liu, X., Zhao, Z., Duan, B., Hu, C., Zhao, X., Guo, Z. (2015b) Effect of applied sulphur on the uptake by wheat of selenium applied as selenite. *Plant Soil* **386,** 35–45.

Liu, X., Zhao,Z., Hu, C., Zhao,X. and Guo, Z. (2015c) Effect of sulphate on selenium uptake and translocation in rape (*Brassica napus* L.) supplied with selenate or selenite. *Plant Soil,* DOI: 10.1007/s11104-015-2699-7.

Longchamp, M., Castrec-Rouelle, M., Biron, P., Bariac, T. (2015) Variations in the accumulation, localization and rate of metabolization of selenium in mature Zea mays plants supplied with selenite or selenate. *Food Chem* **182,**128–135. Doi: 10.1016/j.foodchem.2015.02.137.

Longchamp, M., Angeli, N., Castrec-Rouelle, M. (2016) Effects on the accumulation of calcium, magnesium, iron, manganese, copper and zinc of adding the two inorganic forms of selenium to solution cultures of Zea mays. *Plant Physiology and Biochemistry,* **98**,128-137.

Malik, J.A., Goel, S., Kaur, N., Sharma, S., Singh, I., Nayyar, H. (2012) Selenium antag-onises the toxic effects of arsenic on mungbean (*Phaseolus aureus Roxb*.) plants by restricting its uptake and enhancing the antioxidative and detoxification mechanisms. *Environmental and Experimental Botany* **77,** 242–248.

Malik, J.A., Kumar, S., Thakur, P., Sharma, S., Kaur, N., Kaur, R., Pathania, D., Bhandhari, K., Kaushal, N., Singh, K., Srivastava, A. and Nayyar,H. (2011) Promotion of growth in Mungbean (*Phaseolus aureus Roxb*.) by selenium is associated with stimulation of carbohydrate metabolism. *Biol. Trace Elem. Res.* **143,** 530–539. DOI: 10.1007/s12011-010-8872-1.

Mao, H., Wang, Z.H. and Lyons, G. (2015) Germination-enhancing and zinc-sparing roles for selenium in broccoli. *Acta Agriculturae Scandinavica Section B-Soil and Plant Science* **65** (2),141-149. DOI: 10.1080/09064710.2014.978884.

Mao, H., J. Wang, Z. Wang, Y. Zan, G. Lyons, C. Zou (2014). Using agronomic biofortification to boost zinc, selenium, and iodine concentrations of food crops grown on the loess plateau in China. *J. Soil Sci. Plant Nutr.* **14** (2), 459-470. http://dx.doi.org/10.4067/S0718-95162014005000036

Mechora, S., Stibilj,V. and Germ, M. (2015) Response of duckweed to various concentrations of selenite. *Environ Sci Pollut Res* **22,** 2416–2422. DOI 10.1007/s11356-014-3270-4.

Mechora, S., Stibilj,V., Kreft, I. and Germ,M. (2014) The physiology and biochemical tolerance of cabbage to Se (VI) addition to the soil and by foliar spraying. *Journal of Plant Nutrition,* **37** (13),2157-2169. DOI: 10.1080/01904167.2014.920375.

Mengel, K., Kirkby, E. A., Kosegarten, H., Appel, T. (2001) *Principles of plant Nutrition.* 2nd Edition, International Potash Inst., Berne, Switzerland.

Mitra, G. N. (2015) *Regulation Of Uutrient Uptake By Plants: A Biochemical And Molecular Approach.* DOI 10.1007/978-81-322-2334-4, Springer New Delhi.

Mohapatra, P., R. Swain, K., Mishra, S. K., Behera, T., Swain, P. , Mishra, S. S., Behura, N. C., Sabat,S. C., Sethy, K., Dhama,K. and Jayasankar, P. (2014) Effects of dietary nano-selenium on tissue selenium deposition, antioxidant status and immune functions in layer chicks. *International Journal of Pharmacology,* **10** (3), 160-167. DOI: 10.3923/ijp.2014.160.167.

Mora, M. L., Durán, P., Acuña, A. J., Cartes, P., Demanet,R. and Gianfreda, L. (2015) Improving selenium status in plant nutrition and quality. *Journal of Soil Science and Plant Nutrition,* **15** (2)486-503.

Mostafa, E.M. and Hassan, A.M.A. (2015) The ameliorative effect of selenium on Azolla caroliniana grown under UV-B stress. *Phytoprotection*, **95,** 20-26. DOI: 10.7202/1031954ar.

Mozafariyan, M,, Shekari, L., Hawrylak-Nowak, B. and Kamelmanesh,M.M. (2014) Protective role of selenium on pepper exposed to cadmium stress during reproductive stage. *Biol Trace Elem Res.* **160**(1), 97-107. Doi: 10.1007/s12011-014-0028-2.

Mroczek-Zdyrska, M. and Wójcik, M. (2012) The influence of selenium on root growth and oxidative stress induced by lead in *Vicia faba* L. Minor plants. *Biol Trace Elem Res.* **147** (1-3), 320–328. DOI 10.1007/s12011-011-9292-6.

Nagy, G., Benko, I., Kiraly, G,, Voros, O., Tanczos, B., Sztrik, A., Takacs, T., Pocsi, I., Prokisch, J., Banfalvi, G. (2015) Cellular and nephrotoxicity ′ of selenium species, *Journal of Trace Elements in Medicine and Biology,*http://dx.doi.org/10.1016/j.jtemb.2014.12.011.

Nakabayashi, R. and Saito, K. (2015) Integrated metabolomics for abiotic stress responses in plants. *Current Opinion in Plant Biology* **24**,10-16. http://dx.doi.org/10.1016/j.pbi.2015.01.003.

Nawaz, F., Ashraf, M.Y., Ahmad, R., Waraich, E.A., Shabbir, R.N. and Bukhari,M.A. (2015b) Supplemental selenium improves wheat grain yield and quality through alterations in biochemical processes under normal and water deficit conditions. *Food Chem*. **175**, 350-7. DOI: 10.1016/j.foodchem.2014.11.147.

Nawaz F., Ashraf,M. Y., Ahmad, R., Waraich,E. A. and Shabbir, R. N. (2014) Selenium (Se) regulates seedling growth in wheat under drought stress. *Advances in Chemistry,* Volume 2014, Article ID 143567, 7 pages, doi.org/10.1155/2014/143567.

Nawaz, F., Ashraf, M. Y., Ahmad, R. and Waraich,E. A. (2013) Selenium (Se) seed priming induced growth and biochemical changes in wheat under water deficit conditions. *Biol. Trace Elem. Res.* **151,** 284-293. Doi: 10.1007/s12011-012-9556-9.

Nawaz, F., Ahmad, R., Ashraf, M.Y., Waraich, E.A. and Khan, S.Z. (2015a) Effect of selenium foliar spray on physiological and biochemical processes and chemical constituents of wheat under drought stress. *Ecotoxicol Environ Saf.* **113,** 191-200. DOI: 10.1016/j.ecoenv.2014.12.003.

Naz, F.S., Yusuf, M., Khan, T.A., Fariduddin, Q. and Ahmad,A. (2015) Low level of selenium Increases the efficacy of 24-epibrassinolide through altered physiological and Biochemical traits of Brassica juncea plants. *Food Chemistry,* **185,** 441–448. doi:10.1016/j.foodchem.2015.04.016.

Ojeda A. G., Corrales Escobosa, A.R., Wrobel , K., Yanez Barrientos, E. and Wrobel, K. (2013)Effect of Cd (II) and Se (IV) exposure on cellular distribution of both elements and concentration levels of glyoxal and methylglyoxal in Lepidium sativum. *Metallomics.* **5**(9), 1254-61. Doi: 10.1039/c3mt00058c.

Oraghi Ardebili, N., Saadatmand, S., Niknam, V. and Khavari-Nejad, R. A. (2014) The alleviating effects of selenium and salicylic acid in salinity exposed soybean. *Acta Physiol Plant* **36,** 3199–3205. DOI 10.1007/s11738-014-1686-6.

Owusu-Sekyere A., Kontturi, J., Hajiboland, R., Rahmat, S., Aliasgharzad,N., Hartikainen,H. and Seppänen, M. M. (2013) Influence of selenium (Se) on carbohydrate metabolism, nodulation and growth in alfalfa (*Medicago sativa* L.). *Plant Soil* **373**,541–552. DOI: 10.1007/s11104-013-1815-9.

Pandey, C. and Gupta, M. (2015) Selenium and auxin mitigates arsenic stress in rice (*Oryza sativa* L.) by combining the role of stress indicators, modulators and genotoxicity assay. *Journal of Hazardous Materials* **287**, 384-391.

Pandey P., Ramegowda, V. and Senthil-Kumar, M. (2015) Shared and unique responses of plants to multiple individual stresses and stress combinations: physiological and molecular mechanisms. *Front Plant Sci.* **6,** 723. Doi: 10.3389/fpls.2015.00723.

Pelyhe, C. and Mézes, M. (2013) Myths and facts about the effects of nano selenium infarm animals–mini-review. *Eur. Chem. Bull.,* **2**(12) 1049-1052.

Pennanen, A., Xue, T. and Hartikainen,H.(2002) Protective role of selenium in plant subjected to severe UV irradiation stress. *J. Appl. Bot.,* **76**,66-76.

Pezzarossa, B., Rosellini,I. Borghesi, E., Tonutti, P. and Malorgio, F. (2014) Effects of Se-enrichment on yield, fruit composition and ripening of tomato (*Solanum lycopersicum*) plants grown in hydroponics. *Scientia Horticulturae* **165,** 106–110.http://dx.doi.org/10.1016/j.scienta.2013.10.029.

Pickering, I. J., George, G. N., MacDonald, T.C., Krone,P. H. and Korbas,M. (2016) Synchrotron studies of selenium interactions with heavy elements. In: Global advances in selenium research from theory to application. G. S. Bañuelos, Z.-Q. Lin, L. R. G. Guilherme and A. R. dos Reis (Eds.), *Proceedings Of The 4Th International Conference On Selenium In The Environment And Human Health, Sao Paulo,* Brazil, 18–21 October 2015. CRC, Taylor & Francis Group, London, UK, pp: 43 – 44.

Pilon-Smits, E. A. H. (2015) Selenium in plants. In: U. Luttge, W. Beyschlag (eds.), *Progress in Botany, Progress in Botany* **76**, DOI 10.1007/978-3-319-08807-5_4, Springer International Publishing Switzerland, pp: 93 – 107.

Pilon-Smits, E.A.H., Quinn, C.F,. Tapken, W., Malagoli, M. and Schiavon, M. (2009) Physiological functions of beneficial elements. *Current Opinion Plant Biology* **12,** 267–274.

Pilon-Smits, E. A. H., El-Mehdawi, A. F. , Cappa, J. J., Wang, J., Cochran, A. T., Reynolds,R. J. and M. Sura de Jong (2016) New insights into the multifaceted ecological and evolutionary aspects of plant selenium hyperaccumulation. In: Global advances in selenium research from theory to application. G. S. Bañuelos, Z.Q. Lin, L. R. G. Guilherme and A. R. dos Reis (Eds.), *Proceedings of the 4th International Conference on Selenium in the Environment and Human Health, Sao Paulo,* Brazil, 18–21 October 2015. CRC, Taylor & Francis Group, London, UK, pp: 125 – 126.

Pilon-Smits, E. A. H., Bañuelos,G. S. and Parker,D.

R. (2014) Uptake, metabolism and volatilization of selenium by terrestrial plants. In: A.C. Chang and D. Brawer Silva (Eds.), Salinity and drainage in san joaquin valley, california: science, technology, and policy, *Global Issues in Water Policy* **5**, DOI 10.1007/978-94-007-6851-2_6, Springer Science + Business Media Dordrecht, pp: 147 – 164.

Pilon-Smits, E. A.H. and Quinn, C. F. (2010) Selenium metabolism in plants. In: R. Hell and R.R. Mendel (Eds.), Cell biology of metals and nutrients, *Plant Cell Monographs* 17, DOI 10.1007/978-3-642-10613-2_10, Springer-Verlag Berlin Heidelberg, pp: 225 – 241.

Premarathna, H.L., McLaughlin, M.J., Jason, Kirby,K., Hettiarachchi, G. M., Beak, D., Stacey,S. and Chittleborough, D.J. (2010) Potential availability of fertilizer selenium in field capacity and submerged soils. *Soil Sci. Soc. Am. J.* **74**,1589–1596. doi:10.2136/sssaj2009.0416.

Proietti, P., Nasini,L., Del Buono, D., D'Amato, R ., Tedeschini,E. and Businelli, D. (2013) Selenium protects olive (*Olea europaea* L.) from drought stress. *Scientia Horticulturae* **164,** 165–171. doi:10.1016/j.scienta.2013.09.034.

Qin, S. Y., Zhao, W. I., Li, Z. and Liang, D. L. (2016) Effects of sulfur and selenium interaction on packchoi growth and selenium accumulation. In: Global advances in selenium research from theory to application. G. S. Bañuelos, Z.-Q. Lin, L. R. G. Guilherme and A. R. dos Reis (Eds.), *Proceedings Of The 4Th International Conference On Selenium In The Environment And Human Health, Sao Paulo,* Brazil, 18–21 October 2015. CRC, Taylor & Francis Group, London, UK, pp: 131 – 132.

Qing X., Zhao, X., Hu, C., Wang,P., Zhang, Y. Zhang,X., Wang, P. C., Shi, H., Jia,F. and Qu,C. J. (2015) Selenium alleviates chromium toxicity by preventing oxidative stress in cabbage (*Brassica campestris L. ssp. Pekinensis*) leaves. *Cotoxicology and Environmental Safety* **114**,179–189.

Quinn, C. F., Freeman, J. L. , Reynolds, R. J. B. , Cappa,J. J., Fakra, S. C., Marcus, M. A., Lindblom, E. K., Quinn, S. D., Bennett, L. E. and Pilon-Smits,E. A. H. (2010) Selenium hyperaccumulation offers protection from cell disruptor herbivores. *Plant physiol.* **153**, 1630–1652.

Radwan, N. L., T. A. Salah Eldin, A.A. EL-Zaiat and M. A.S.A. Mostafa (2015) Effect of dietary nano-selenium supplementation on selenium content and oxidative stability in table eggs and productive performance of laying hens. *International Journal of Poultry Science* **14** (3), 161-176. ISSN 1682-835.

Ramegowda, V. and Senthil-Kumar, M. (2015)Review: the interactive effects of simultaneous biotic and abiotic stresses on plants: mechanistic understanding from drought and pathogen combination, *Journal of Plant Physiology,* **176,** 47–54. http://dx.doi.org/10.1016/j.jplph.2014.11.008.

Ramos, S. J., Yuan, Y. X., Faquin, V., Guilherme, L. R. G. and L Li (2011) Evaluation of genotypic variation of broccoli (Brassica oleracea var. italica) in response to selenium treatment. *Journal of Agricultural and Food Chemistry* **59**, 3657-3665.

Rashid, M. M. and Z.-Q. Lin (2016). Partionting of SeNPs in the water soluble and the exchangeable fractions and effects of soil organic matter and incubation time. In: Global advances in selenium research from theory to application. G. S. Bañuelos, Z.-Q. Lin, L. R. G. Guilherme and A. R. dos Reis (Eds.), *Proceedings Of The 4Th International Conference On Selenium In The Environment And Human Health, Sao Paulo,* Brazil, 18–21 October 2015. CRC, Taylor & Francis Group, London, UK, pp: 35 – 36.

Rastgoo, S. and A. A. Sadeghi (2015). Effect of nano-selenium on plasma antioxidant status and reproductive system function of female rats exposed to oxidative stress induced by doxorubicin. *Biological Forum – An International Journal* **7**(1), 187-191.

Rayman, M. P. (2000). The importance of selenium to human health. *Lancet*. **356**, 233-241.

Rezvanfar, MA, MA Rezvanfar, AR Shahverdi, A. Ahmadi, M. Baeeri, A. Mohammadirad and M. Abdollahi (2013). Protection of cisplatin-induced spermatotoxicity, DNA damage and chromatin abnormality by selenium nano-particles. *Toxicology and Applied Pharmacology* **266**, 356–365. http://dx.doi.org/10.1016/j.taap.2012.11.025

Rico, C. M., J. R. Peralta-Videa and J.L. Gardea-Torresdey (2015). Chemistry, biochemistry of nanoparticles, and their role in antioxidant defense system in plants. In: M.H. Siddiqui et al. (Eds.), *Nanotechnology and Plant Sciences,* Springer International Publishing Switzerland pp: 1 – 17. DOI 10.1007/978-3-319-14502-0_1

Sadeghian, S., G. A. Kojouri and A. Mohebbi (2012). Nanoparticles of selenium as species with stronger physiological effects in sheep in comparison with sodium selenite. *Biol Trace Elem Res.* **146**(3), 302–308. Doi: 10.1007/s12011-011-9266-8

Sae-Lee, N., O. Kerdchoechuen and N. Laohakunjit (2012). Chemical qualities and phenolic compounds of Assam tea after soil drench application of selenium and aluminium. *Plant Soil* **356**, 381–393. DOI 10.1007/s11104-012-1139-1

Saidi, I., Y. Chtourou and W. Djebali (2014) Selenium alleviates cadmium toxicity by preventing oxidative stress in sunflower (Helianthus annuus) seedlings. *Journal of Plant Physiology* **171** (5), 85-91.

Sajedi, NA, MR Ardakani, H Madani, A Naderi and M. Miransari (2011) The effects of selenium and other micronutrients on the antioxidant activities and yield of corn (Zea mays L.) under drought stress. *Physiol Mol Biol Plants.* **17**(3), 215-22. Doi: 10.1007/s12298-011-0067-5.

Sarkar, B., S. Bhattacharjee, A. Daware, P. Tribedi, K. K. Krishnani and P. S. Minhas (2015). Selenium nanoparticles for stress-resilient fish and livestock. *Nanoscale Research Letters* **10**, 371. DOI 10.1186/s11671-015-1073-2

Sasmaz M., B. Akgül and A. Sasmaz (2015). Distribution and accumulation of selenium in wild plants growing naturally in the gumuskoy (kutahya) mining area, turkey. *Bull Environ Contam Toxicol.* **94**(5), 598-603. Doi: 10.1007/s00128-015-1527-3.

Schiavon, M., S. dall'Acqua, A. Mietto, E. A. H. Pilon-Smits, P. Sambo, A. Masi and M. Malagoli (2013). Selenium fertilization alters the chemical composition and antioxidant constituents of tomato (Solanum lycopersicon L.). *J. Agric. Food Chem.* **61**, 10542−10554. DOI: dx.doi.org/10.1021/jf4031822

Schiavon, M.; Pilon, M.; Malagoli, M. and E.A. Pilon-Smits (2015). Exploring the importance of sulfate transporters and ATP sulphurylases for selenium hyperaccumulation—A comparison of Stanleya pinnata and Brassica juncea (Brassicaceae). *Front. Plant Sci.,* **6**, 1–13. Doi: 10.3389/fpls.2015.00002.

Schwarz K and CM Foltz (1957). Selenium as an integral part of factor 3 against dietary necrotic liver degeneration. *J. Am. Chem. Soc.* **79** (12), 3292–3293. DOI: 10.1021/ja01569a087

Selim, N.A., N. L. Radwan, S. F. Youssef, T. A. Salah Eldin and S. Abo Elwafa (2015). Effect of inclusion inorganic, organic or nano selenium forms in broiler diets on: 2-physiological, immunological and toxicity statuses of broiler chicks. *International Journal of Poultry Science* **14** (3), 144-155. ISSN 1682-8356

Sharma S, N Kaur, S Kaur, H Nayyar (2014). Ascorbic acid reduces the phytotoxic effects of selenium on rice (*Oryza Sativa* L.) by up-regulation of antioxidative and metal-tolerance mechanisms. *J Plant Physiol Pathol* **2**,3. Doi.org/10.4172/2329-955X.1000128

Shinmachi F, Buchner P, Stroud J, Parmar S, Zhao F, McGrath S, Hawkesford MJ (2010). Influence of sulfur deficiency on the expression of specific sulfate transporters and the distribution of sulfur, selenium, and molybdenum in wheat. *Plant Physiol.* **153** (1), 327–36. DOI: 10.1104/pp.110.153759

Smolen, S., Kowalska I, Sady W (2014). Assessment of biofortification with iodine and selenium of lettuce cultivated in the NFT hydroponic system. *Scientia Horti* **166**, 9-16.

Soleimanzadeh, H. (2012). Response of sunflower (Helianthus annuus L.) to selenium application under water stress. *World Applied Sciences Journal* **17** (9), 1115-1119. ISSN 1818-4952.

Suchý, P., E. Straková and I. Herzig (2014). Selenium in poultry nutrition: a review. *Czech J. Anim. Sci.,* **59** (11), 495–503

Suzuki, N., R. M. Rivero, V. Shulaev, E. Blumwald and R. Mittler (2014). Abiotic and biotic stress combinations. *New Phytologist* **203**, 32–43. Doi: 10.1111/nph.12797.

Talukdar, D. (2013) Selenium priming selectively ameliorates weed: induced phytotoxicity by modulating antioxidant defense components in lentil (Lens culinaris Medik.) and grass Pea (*Lathyrus sativus* L.). *Annual Review & Research in Biology* **3**(3), 195-212.

Tamaoki M, Freeman JL, Pilon-Smits EAH (2008). Cooperative ethylene and jasmonic acid signaling regulates selenite resistance in Arabidopsis thaliana. P*lant Physiol* **146**,1219–1230.

Tang, H., Liu, Y. X. Gong, G. Zeng, B. Zheng, D. Wang, Z. Sun, L. Zhou and Zeng, X. (2015) Effects of selenium and silicon on enhancing antioxidative capacity in ramie (Boehmeria nivea L. Gaud.) under cadmium stress. *Environ Sci Pollut Res* **22**,9999–10008. DOI 10.1007/s11356-015-4187-2

Tatsuo, K. (2015). *Iodine Chemistry And Applications.* John Wiley & Sons, Inc., New Jersey, USA

Tedeschini E., Proietti, P., Timorato, V., D'Amato, R., Nasini, L., Dei Buono, D., Businelli, D., Frenguelli, G. (2015). Selenium as stressor and antioxidant affects pollen performance in Olea europaea. *Flora,* http://dx.doi.org/doi:10.1016/j.flora.2015.05.009

Thiruvengadam, M. and I. M. Chung (2015). Selenium, putrescine, and cadmium influence health-promoting phytochemicals and molecular level effects on turnip. *Food Chem.***173**, 185–193.

Torres, S. K., V. L. Campos, C. G. León, S. M. Rodríguez-Llamazares, S. M. Rojas, M. González, C. Smith and M. A. Mondaca (2012). Biosynthesis of selenium nanoparticles by Pantoea agglomerans and their antioxidant activity. *J. Nanopart. Res.* **14**, 1236 – 1245. DOI 10.1007/s11051-012-1236-3

Tripathi, V., L. F. Fracetob and P. C. Abhilash (2015a). Sustainable clean-up technologies for soils contaminated with multiple pollutants: Plant-microbe-pollutant and climate nexus. *Ecological Engineering* **82**, 330–335. http://dx.doi.org/10.1016/j.ecoleng.2015.05.027.

Turakainen, M., H. Hartikainen and M. M. Seppänen (2004). Effects of selenium treatments on potato (Solanum tuberosum L.) growth and concentrations of soluble sugars and starch. *J Agric Food Chem* **52**, 5378–5382.

USGS, United States Geological Survey (2015) Mineral commodity summaries 2015: U.S. Geological Survey, Reston, Virginia, 196 p., http://dx.doi.org/10.3133/70140094.

Van Hoewyk, D. (2013) A tale of two toxicities: malformed selenoproteins and oxidative stress both contribute to selenium stress in plants. *Annals of Botany,* pp: 1 – 8. Doi:10.1093/aob/mct163

Wan, Y. N., S. L. Yuan, Z. Luo and H. F. Li (2016)Effect of selenium on cadmium uptake and translocation by rice seedlings. In: Global advances in selenium research from theory to application. G. S. Bañuelos, Z.-Q. Lin, L. R. G. Guilherme and A. R. dos Reis (Eds.), *Proceedings Of The 4Th International Conference On Selenium In The Environment And Human Health,* Sao Paulo, Brazil, 18–21 October 2015. CRC, Taylor & Francis Group, London, UK, pp: 143 – 144.

Wang, X., Tam, N., Fu, F., Ametkhan, S., Ouyang,A. Y., Ye, Z. (2014) Selenium addition alters mercury uptake, bioavailability in the rhizosphere and root anatomy of rice (*Oryza sativa*). *Ann Bot.* **114**(2), 271-8. Doi: 10.1093/aob/mcu117.

Wang, H., Zhang, J. and Yu, H. (2007) Elemental selenium at nano size possesses lower toxicity without compromising the fundamental effect on selenoenzymes: Comparison with selenomethionine in mice. *Free Radic. Biol. Med.* **42**1524–1533.

Wang, J., Mahajan,R., Jones,L. and Lin,Z.Q. (2016) Biogenic volatilization of nanoscale selenium particles in the soil- Stanleya pinnata system. In: Global advances in selenium research from theory to application. G. S. Bañuelos, Z.Q. Lin, L. R. G. Guilherme and A. R. dos Reis (Eds.), *Proceedings Of The 4Th International Conference On Selenium In The Environment And Human Health, Sao Paulo,* Brazil, 18–21 October 2015. CRC, Taylor & Francis Group, London, UK, pp: 11 – 12.

Wang, Y.D., X. Wang,Y.S. and Wong, Y.S. (2013) Generation of selenium-enriched rice with enhanced grain yield, selenium content and bioavailability through fertilisation with selenite. *Food Chemistry* **141** (3), 2385–2393. http://dx.doi.org/10.1016/j.foodchem.2013.05.09.

White, P. J. and Brown,P. H. (2010) Plant nutrition for sustainable development and global health. *Annals of Botany* **105,** 1073–1080. doi:10.1093/aob/mcq085.

White, P. J. and Broadley, M. R. (2005) Biofortifying crops with essential mineral elements. Trends in *Plant Science* Vol. **10** (12), 586 – 593. doi:10.1016/j.tplants.2005.10.001.

White, P.J., Broadley, M.R., Bowen, H.C. and Johnson,S.E. (2007) Selenium and its relationship with sulfur. In: Hawkesford, M.J., de Kok, L.J. (Eds.), Sulfur in Plants – An Ecological Perspective. Springer, London, UK, pp. 225–252.

White, P.J., Bowen, H.C., Parmaguru, P., Fritz, M., Spracklen, W.P., Spiby, R.E., Meacham, M.C., Mead, A., Harriman, M., Trueman, L.J., Smith, B.M., Thomas, B., Broadley, M.R. (2004) Interactions between selenium and sulphur nutrition in Arabidopsis thaliana. *J. Exp. Bot* **55**, 1927–1937.

Winkel, L. H. E., Vriens, B., Jones, G. D., L. S. Schneider, E. Pilon-Smits and G. S. Bañuelos (2015) Selenium cycling across soil-plant-atmosphere interfaces: a critical review. *Nutrients,* **7**, 4199-4239. Doi: 10.3390/nu7064199.

Wu, X. J. Song, B., Wu, Li, T. Li, X. (2014) Geochemical processes controlling dissolved selenium in the Changjiang (Yangtze) Estuary and its adjacent waters. *Acta Oceanologica Sinica* **33** (10), 19–29. DOI: 10.1007/s13131-014-0537-z

Wu, J., Wu, Z. Li, M. Bañuelos, G. S. and Lin,Z.Q. (2016a) Selenium improves the biochemical activity of Cryptococcus Laurentii against Penicillium expansum in tomato fruit. In: Global advances in selenium research from theory to application. G. S. Bañuelos, Z.Q. Lin, L. R. G. Guilherme and A. R. dos Reis (Eds.), *Proceedings Of The 4Th International Conference On Selenium In The Environment And Human Health, Sao Paulo,* Brazil, 18–21 October 2015. CRC, Taylor & Francis Group, London, UK, pp: 103 – 104.

Wu, J., Z. Wu, M. Li, Y. Deng, G. S. Bañuelos and Z.-Q. Lin (2016b). Effects of selenium –enrichment on fruits ripening and senescence in mulberry trees. In: Global advances in selenium research from theory to application. G. S. Bañuelos, Z.-Q. Lin, L. R. G. Guilherme and A. R. dos Reis (Eds.), *Proceedings Of The 4Th International Conference On Selenium In The Environment And Human Health,* Sao Paulo, Brazil, 18–21 October 2015. CRC, Taylor & Francis Group, London, UK, pp: 181 – 182.

Xun W., L. Shi, W. Yue, C. Zhang, Y. Ren and Q. Liu (2012). Effect of high-dose nano-selenium and selenium–yeast on feed digestibility, rumen fermentation, and purine derivatives in sheep. *Biol Trace Elem Res* **150**,130–136. DOI 10.1007/s12011-012-9452-3

Yao X, Chu J, He X, and Ba C. (2011). Protective role of selenium in wheat seedlings subjected to enhanced UV-B radiation. *Russian Journal of Plant Physiology* **58**, 283–289.

Yao, X., Chu, J,, Liang, L., Geng, W., LI, J. and Hou, G. (2012) Selenium improves recovery of wheat seedlings at rewatering after drought stress. *Russian Journal of Plant Physiology* **59**, 701–707.

Yao XQ, Chu JZ and Ba CJ. (2010a). Antioxidant responses of wheat seedlings to exogenous selenium supply under enhanced ultraviolet-B. *Biological Trace Element Research* **136**, 96–105.

Yao XQ, Chu JZ and Ba CJ. (2010b). Responses of wheat roots to exogenous selenium supply under enhanced ultraviolet-B. *Biological Trace Element Research* **137**, 244–252.

Yao XQ, Chu JZ, and Wang GY. (2009a). Effects of selenium on wheat seedlings under drought stress. *Biological Trace Element Research* **130**, 283–290.

Yao X, JZ Chu and GY Wang (2009b). Effects of drought stress and selenium supply on growth and physiological characteristics of wheat seedlings. *Acta Physiologiae Plantarum* **31**, 1031–1036.

Yao, X., C. Jian, H. Xueli, L. Binbin, L. Jingmin and Y. Zhaowei (2013). Effects of selenium on agronomical characters of winter wheat exposed to enhanced ultraviolet-B. *Ecotoxicol. Environ. Saf.* **92**, 320–326.

Yasin, M., A. F. El-Mehdawi, A. Anwar, E. A. Pilon-Smits and M. Faisal (2015). Microbial-enhanced selenium and iron biofortification of wheat (triticum aestivum L.)—applications in phytoremediation and biofortification. *Int J. Phytoremediat.,* **17**, 341–347.

Yin, X., J. Song, Z. Li, W. Qian, C. Yao, Y. Loo and L. Yuan (2016). Accumulation of mercury and selenuim by Oryza sativa from the vicinity of secondary copper smelters in Fuyang, Zheijiang, China. In: Global advances in selenium research from theory to application. G. S. Bañuelos, Z.-Q. Lin, L. R. G. Guilherme and A. R. dos Reis (Eds.), *Proceedings Of The 4Th International Conference On Selenium In The Environment And Human Health, Sao Paulo,* Brazil, 18–21 October 2015. CRC, Taylor & Francis Group, London, UK, pp: 135 – 136.

Yuan J., Hu, M. and Zhou,Z. (2013a) Selenium treatment mitigates the effect of lead exposure in Coleus blumei Benth. *Journal of Environmental Analytical Toxicology* **3,** 191. DOI: 10.4172/2161-0525.1000191

Yuan J.-H., M.-H. Hu and Z.-H. Zhou (2013b). Selenium alleviates Coleus from oxidative damage under Pb stress by resource allocation and antioxidant defense system. *Research Journal of Applied Sciences, Engineering and Technology* **6**(9), 1606-1613. ISSN: 2040-7459

Zhang H, Feng X, Jiang C, Li Q, Liu Y, Gu C, Shang L, Li P, Lin Y, Larssen T (2014) Understanding the paradox of selenium contamination in mercury mining areas: high soil content and low accumulation in rice. *Environmental Pollution,* **188**,27–36. http://dx.doi.org/10.1016/j.envpol.2014.01.012

Zhang H, Feng X, Zhu J, Sapkota A, Meng B, Yao H, Qin H, Larssen T (2012). Selenium in soil inhibits mercury uptake and translocation in rice (*Oryza sativa* L.). *Environmental Science & Technology.* **46**, 10040–10046. DOI: 10.1021/es302245r

Zhang H, Feng XB, Larssen T (2013). Interaction of selenium and mercury in soil-plant system in mercury mining areas and their combined exposure and risk. In: *Selenium in the Environment and Human Health.* CRC Press, pp:201–202. DOI: 10.1201/b15960-89.

Zhang H. (2014). Interactions of mercury and selenium in soil-rice system. In: H. Zhang (Ed.), *Impacts Of Selenium On The Biogeochemical Cycles Of Mercury In Terrestrial Ecosystems In Mercury Mining Areas,* Springer Theses, DOI: 10.1007/978-3-642-54919-9_10, pp: 135 – 149. Springer-Verlag Berlin Heidelberg

Zhang J., X. Wang and T. Xu (2008). Elemental selenium at nano size (Nano-Se) as a potential chemopreventive agent with reduced risk of selenium toxicity: comparison with se-methylselenocysteine in mice. *Toxicol. Sci.* **101**, 22–31.

Zhang JS, Gao XY, Zhang LD, Bao YP (2001). Biological effects of a nano red elemental selenium. *BioFactors* **15**, 27–38.

Zhang, Y., H. Jiang, H. Zang, G. Tan, Li, M. Yuan,L. and Yin, X. (2016) Antifungal activity of selenium on two plant pathogens Sclerotinia Sclerotiorum and Colletotrichum gloeosporiodes. In: Global advances in selenium research from theory to application. G. S. Bañuelos, Z.-Q. Lin, L. R. G. Guilherme and A. R. dos Reis (Eds.), *Proceedings Of The 4Th International Conference On Selenium In The Environment And Human Health, Sao Paulo,* Brazil, 18–21 October 2015. CRC, Taylor & Francis Group, London, UK, pp: 105 – 106.

Zhao, J., Gao, Y., Li, Y., Hu, Y., X. Peng, Dong, Y., Li, B., Chen, C. and Chai, Z. (2013) Selenium inhibits the phytotoxicity of mercury in garlic (Allium sativum). *Environ. Res.*, **125**, 75–81. http://dx.doi.org/10.1016/j.envres.2013.01.010.

Zhao, J., Y. Li, Y. Li, Y. Gao, B. Li, Y. Hu, Y. Zhao and Z. Chai (2014) Selenium modulates mercury uptake and distribution in rice (*Oryza sativa* L.), in correlation with mercury species and exposure level. Metallomics, 6: 1951-1957. DOI: 10.1039/c4mt00170b.

Zhao, H., Huang, J., Li, Y., Song, X., Luo, J., Yu, Z. and Ni, D. (2016) Natural variation of selenium concentration in diverse tea plant (*Camellia sinensis*) accessions at seedling stage. *Scientia Horticulturae,* **198,** 163-169.

Zhu, Y.G., Y. Huang, Y. Hu, Y. Liu and Christie,P. (2004) Interactions between selenium and iodine uptake by spinach (*Spinacia oleracea* L.) in solution culture. *Plant and Soil* **261**(1), 99-105. DOI: 10.1023/B:PLSO.0000035539.