ADDITION OF TRACE ELEMENTS TO COMMON AND TARTARY BUCKWHEAT (*FAGOPYRUM ESCULENTUM* AND *F. TATARICUM*)

DODAJANJE ELEMENTOV V SLEDOVIH NAVADNI IN TATARSKI AJDI (*FAGOPYRUM ESCULENTUM* IN *F. TATARICUM*)

Mateja GERM[1], Nina KACJAN MARŠIĆ[1], Helena ŠIRCELJ[1], Ana KROFLIČ[2], Ana JERŠE[2], Vekoslava STIBILJ[2], Drena GADŽO[3], Cheol-Ho PARK[4] & Aleksandra GOLOB[1]

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ABSTRACT

Addition of trace elements to *Fagopyrum esculentum* and *F. tataricum*

Plants need at least 14 elements for normal functioning. Selenium (Se) is on the list of beneficial elements for plants, since it has many positive effects in a propriate concentrations. Iodine (I) is not yet classified on that list since there are not enough studies about the effect of I on plants. Selenium in plants may cause a delay of senescence and promote the growth of the ageing seedlings. Selenium also exhibits protective role in UV treated plants, plants, exposed to water shortage, and in plants, exposed to high or low temperature. High concentration of Se was reported to cause physiological disturbances in plants due to Se binding to cysteine and methionine molecules instead of S, and the inclusion of selenocysteine and selenomethionine in proteins. I might have a positive effect on plants, including its protective role in antioxidant activities in plants, exposed to different stress conditions. Both elements are in deficit in human nutrition in many countries worldwide. I and Se are needed for the optimal function of thyroid gland, thus simultaneous biofortification of crops is feasible for areas deficient in both elements. Selenium and I interfere with each other in pea, common buckwheat plants and in kohlrabi. Sulphur (S) and Se have similar chemical properties, and the assimilation of Se and S follows the S metabolic pathway. S induced the accumulation of Se in Tartary buckwheat in field experiment. Silicon (Si) enhances plant strength, ameliorates the negative effects of salinity, drought, and high or low temperatures, amelio-

IZVLEČEK

Dodajanje elementov v sledovih navadni in tatarski ajdi (*Fagopyrum esculentum* in *F. tataricum*)

Rastline potrebujejo vsaj 14 elementov za normalno rast. Selen (Se) je na seznamu koristnih elementov za rastline, saj ima v ustreznih koncentracijah veliko pozitivnih učinkov na rastline. Jod (I) na ta seznam še ni uvrščen, saj ni dovolj raziskav o vplivu I na rastline. Selen pri rastlinah lahko zakasni proces staranja in pospeši rast sadik. Selen kaže tudi zaščitno vlogo pri rastlinah, izpostavljenih UV žarkom, rastlinah, ki so izpostavljene pomanjkanju vode, in rastlinah, ki so izpostavljene visokim ali nizkim temperaturam. Raziskovalci poročajo, da visoke koncentracije Se povzročajo fiziološke motnje v rastlinah zaradi vezave Se na molekule cisteina in metionina na mesto žvepla in vključitve selenocisteina in selenomethionina v beljakovine. Jod pozitivno vpliva na rastline, vključno s povečanjen njihove antioksidativne aktivnosti pri rastlinah, ki so izpostavljene različnim stresnim razmeram. V mnogih državah po svetu oba elementa primanjkujeta v prehrani ljudi. Jod in Se potrebujemo za optimalno delovanje ščitnice, zato je sočasna biofortifikacija poljščin smiselna na območjih s pomanjkanjem obeh elementov. Dodatek Se in I vplivata na akumulacijo drug drugega pri grahu, navadni ajdi in pri kolerabici. Žveplo (S) in Se imata podobne kemijske lastnosti, asimilacija Se in S pa sledi metabolni poti S. Žveplo je v poljskem poskusu, kjer smo rastlinam foliarno dodajali hkrati oba elementa, povzročilo povečano kopičenje Se v tatarski ajdi. Silicij (Si) povečuje trdnost rastlin, blaži negativne učinke

[1] University of Ljubljana, Biotechnical Faculty, Jamnikarjeva 101, Ljubljana, Slovenia, mateja.germ@bf.uni-lj.si, nina.kacjan.marsic@bf.uni-lj.si, helena.sircelj@bf.uni-lj.si, golob.aleksandra@bf.uni-lj.si

[2] Department of Environmental Sciences, "Jožef Stefan" Institute, Ljubljana, Jamova c. 39, Ljubljana, Slovenia, ana.kroflic@gmail.com, ana.jerse@gmail.com, vekoslava.stibilj@gmail.com

[3] Faculty of Agriculture and Food Science, University of Sarajevo, Zmaja od Bosne 8, Bosnia and Herzegovina, d.gadzo@ppf.unsa.ba,

[4] Department of Bio-Health Technology, College of Biomedical Science, Kangwon National University, Chunchon, Korea, chpark@kangwon.ac.kr

rates metal toxicity, and increases plant resistance to different pathogens and herbivores.

Key words: buckwheat, Fagopyrum, selenium, iodine, sulphur, silicon

slanosti, suše in visokih ali nizkih temperatur, blaži strupenost kovin in povečuje odpornost rastlin na patogene in rastlinojede.

Ključne besede: ajda, Fagopyrum, selen, jod, žveplo, silicij

IODINE

In nature, iodine can be found in various forms, such as inorganic sodium salts and potassium salts, iodate and iodide, inorganic and organic iodine (Ahad & Ganie 2010). Plant root cells take up I in the form iodide anion, which follows the chloride transport pathway (White & Broadley 2009). Lack of iodine in the human body is due to insufficient uptake of iodine by food. About two billion people worldwide have iodine deficiency problems. The most effective way of providing enough iodine in the diet is by iodizing salt. Excessive salting of food can cause health problems in humans. An effective solution to iodine deficiency in food for humans is biofortification of plants with iodine (Tonacchera et al. 2013). Iodine is not essential in terrestrial plants. Medrano-Macias et al. (2016) in their review paper reported that there are studies showing beneficial effects of iodine in plants, including better growth, and changes the tolerance to stress and also antioxidant capacity, on the other hand some studies report that the addition of iodine cause no response or even have adverse effects. Uptake of iodine by plants from the soil depend from adsorption–desorption processes in the soil, amount of organic compounds… (Zia et al. 2014). Weng et al. (2013) evidenced that leaf vegetables have higher absorption capacity than fruit vegetable. Smoleń et al. (2011) reported that plants take up iodine through the root system, preferably as iodide. Iodine transport relies more on phloem than on xylem (Blasco et al. 2011). In the recent study of Germ et al. (2019) it was proven that iodine transport exists through phloem, since the amount of iodine increased in seeds in buckwheat plants, previously foliarly treated with iodide and iodate. Golob et al. (2020) shown that similar levels of Se and I in the leaves and tubers in kohlrabi plants showed the translocation of both elements from the leaves to the tubers through the phloem. Transport of iodine by phloem has been previously also evidenced in tomato (Landini et al. 2011). In the study of Dai et al. (2006) it was shown that iodide (I^-) and iodate (IO_3^-) added to the soil, did not significantly affect spinach biomass production. The added iodine can also have a phytotoxic effect, leading to a decrease in biomass and thus reducing crop production (Blasco et al. 2011). Machowiak et al. (2005) found that iodide was more toxic than iodate. Later researchers (Blasco et al. 2012) found that iodide was more available than iodate and at the same time demonstrated that iodine concentration in vegetables was higher when iodide was added than when iodate was added to plants. Blasco et al. (2011) found that the presence of iodide reduced the biomass of the crop of lettuce, while the presence of iodate increased the biomass of the crop.

SELENIUM

Selenium is a trace element that is essential nutrient for humans and animals but also acts environmental toxicant; the boundary between the two is narrow and depends on its concentration, chemical form, and other environmental parameters (Fan et al. 2002). The essentiality of Se to higher plants, however, is still under debate in the scientific world. Selen is harmful for plants in high concentrations, but it has beneficial effects at low concentrations. Health risks for humans and animals can occur in areas where soils are low in bioavailable Se. Although higher plants do not to require Se, in Finland, where the amount of Se in soils is low, the supplementation of fertilizers with sodium selenate affects positively the whole food chain from soil to plants, animals and humans, including the amount of plant yields (Alfthan et al. 2014). Selenium is toxic at high concentrations due to incorporation of Se in place of sulphur in amino acids, with subsequent alteration of protein three-dimensional structure and impairment of enzymatic function (Brown and Shrift 1981). Gorše et al. (2018) measured chlorophyll *a*, anthocyanins, UV absorbing compounds and rutin in Tartary buckwheat sprouts, which become very popular in the food production and nutrition. Sprouts contain significant amount of vitamins and mineral. Amendment of sprouts with iodine and selenium may prevent endemic deficiency of these elements for humans and animals. Tartary buckwheat seeds were soaked in solutions with selenate, iodate or in selenate + iodate. Germination rate of sprouts form seeds, soaked in solution of iodate and combination of selenate and iodate was lower comparing to control group. However, there was no effect of the treatments on the amount of chlorophylls, anthocyanins and UV absorbing compounds. The amount of flavonoid rutin, which is important antioxidant, was the highest in untreated sprouts.

Kreft et al. (2013) studied the impact of Se on foliarly treated Tartary buckwheat. Plants effectively took Se and transported it into the seeds, where its concentration was more than twice as high as in untreated plants. The seeds were then collected and sown to obtain the progeny of Se-treated plants. Three weeks after germination, the Se-treated progeny plants had higher respiratory potential measured via electron transport system (ETS) activity compared to the controls. The potential photochemical efficiency of photosystem (PS) II was also higher in the Se-treated progeny plants than the controls. In adult plants, the leaves dry mass was greater in the Se-treated progeny plants than the control plants. This study demonstrates an impact of Se in Tartary buckwheat on the progeny plants of Se sprayed plants showing an epigenetic effect. Golob et al. (2015) found out that when Se was added to Tartary buckwheat plants, the highest content of Se was found in leaves, followed by seeds and stems. Edible parts of Tartary buckwheat plants were safe for human consumption regarding recommended Se concentration for humans. Authors stated that soil fertilization with 0.5 and 10 mg Se L^{-1} and foliar fertilization with 0.5 mg Se L^{-1} are applicable for cultivation of Tartary buckwheat as a functional food enriched with Se. Golob et al. (2016) foliarly sprayed Tartary buckwheat and hybrid buckwheat with sodium selenate. They found out that in both taxa of buckwheat, Se content was significantly higher in treated plants than in controls. Seeds contained the highest Se concentrations in hybrid and Tartary buckwheat. The main Se species found was selenomethionine. Selenium had positive effect on physiological characteristics like photochemical efficiency of PS II in Tartary buckwheat and hybrid buckwheat. Regarding the concentration of Se in both buckwheat taxa and selenomethionine as the dominant chemical species of Se, Se-enriched buckwheat is a potential source of dietary Se for animals and humans. In addition, Tartary buckwheat sprouts enriched with 30 mg Se/L are a potential source of dietary Se, since concentration of Se does not exceed recommended daily allowance for healthy adults (Štrekelj et al. 2014). Ožbolt et al. (2008) evidenced in their study that soaking seeds of common buckwheat before sowing in a 20 mg SeVI/L solution is a suitable method for obtaining high yield of buckwheat herb with a high, but nutritionally safe, level of Se as well as flavonoids.

To conclude, common buckwheat, Tartary buckwheat and hybrid buckwheat have ability to absorb Se in concentrations, which are safe for human nutrition if Se is added to plants in proper concentrations.

IODINE AND SELENIUM

I and Se are needed for the normal function of thyroid gland, thus simultaneous biofortification of crops is feasible for areas deficient in both elements. Iodine and selenium are not essential elements for plants but both play important roles in human and animal organisms (Smoleń et al. 2014). There are some studies focused on the effect of Se and I on plant physiological and biochemical characteristics (Zhu et al. 2004, Smoleń et al. 2014, 2016, 2019, Jerše et al. 2017, 2018, Germ et al. 2019, Golob et al. 2020). There was no effect of Se (SeO_3^{2-}, SeO_4^{2-}), I (I^-, IO_3^-) and their combination on the germination, amount of chlorophylls, anthocyanins and potential photochemical efficiency of PS II in pea sprouts. On the other hand, all treatments lowered biomass or height of the plants in pea sprouts (Jerše et al. 2017). There was also no effect of soaking of seeds in Se, I or their combinations on common buckwheat microgreens regarding photochemical efficiency of PS II. Germination was unaffected by all combinations with Se and I. Mean seed yield in plants, foliarly treated with both forms of Se and I and their combinations, was similar in treated and control plants (Germ et al. 2019). The simultaneous addition of Se and I has an antagonistic or synergistic effect on accumulation of both elements in common buckwheat plants, thus, biofortification of buckwheat microgreens with Se and I should be performed with care. The biofortification of microgreens with iodate should be delivered at reasonable low concentration, to prevent exceeding the recommended daily intake of this element for humans (Germ et al. 2019).

SULPHUR AND SELENIUM

Due to chemical similarities between selenium and sulphur (S), the uptake, transport and assimilation of selenate follow the sulphate pathway and selenate enters root cells via sulphate transporters. Golob et al. (2016) foliarly treated Tartary buckwheat and common buckwheat plants with solutions of selenate and/or sulphate in order to study the effect of sulphur on selenium accumulation in plants. The concentration of Se in all plant parts was similar in control and S treated plants in both species. However, in Tartary buckwheat the concentration of Se was higher in S and Se treated plants comparing to plants treated only with Se. Sulphur enhanced Se accumulation in all parts of Tartary buckwheat. Selenate exposure competes with sulphate in the growth media, that stimulated the sulphate starvation pathway and activate sulphate transporters, leading to higher accumulation of selenate. Authors also shown that it is possible to produce grain and herb of Tartary and common buckwheat containing appropriate amounts of Se for food without affecting the yield of the plants.

SILICON

Silicon (Si) is important element for plant structure and has very important protective role in plants. It improves their potential to cope with various stresses including drought, extreme temperatures, herbivory and pathogen attacks. Accumulation of silicon differs between different plant taxa and also changes during plant development, resulting to differences in their sensitivity to environmental parameters. Silicon uptake in plants depends on transpiration stream (Grašič et al. 2019). Common and Tartary buckwheat were foliarly treated with different concentration of silicon. Height, number of side branches, number of leaves, dry mass of the grains, leaves and stems and amount of rutin were measured in control and treated groups.

CONCLUSION

In conclusion, addition of selenium led to the accumulation of this element in buckwheat plants. Biofortification with selenium and iodine in different forms simultaneously for human nutrition should be done with care because of synergistic or antagonistic effects of each of these elements.

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