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Impact of UV radiation and selenium on two buckwheat species

Vpliv UV sevanja in tretiranja s Se na dve vrsti ajde

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Abstract: The impact of selenium (Se) addition and UV radiation on Tartary buckwheat and hybrid buckwheat were studied. Both buckwheat species grew outdoors at the experimental field of the Biotechnical Faculty in Ljubljana. They were exposed to four different treatments regarding the UV radiation (ambient or reduced) and added Se (naturally accessible or foliary treated with Na selenate in concentration 10 mg Se L^{-1}). The content of pigments (chlorophyll *a* and *b*, carotenoids, anthocyanins) and UV absorbing compounds, transpiration rate, photochemical efficiency of photosystem II (PS) II and respiratory potential were measured. At the end of experiment we determined the biomass of different plant parts. The results showed that irrespective of the buckwheat species the added Se lowered the content of chlorophyll *a* and carotenoids, while it increased the effective quantum yield of PS II and transpiration rate. UV radiation reduced the content of anthocyanins only. Se and UV-B radiation as independent factors exerted no impact on buckwheat yield. Hybrid buckwheat had a higher physiological activity than the Tartary buckwheat yet a smaller biomass of plant parts, including reduced yield. Ambient UV radiation had a slightly negative impact on hybrid buckwheat while it had no noticeable negative impact on Tartary buckwheat. The Se treated Tartary and hybrid buckwheat were suitable for human and animal diet regarding to Se concentrations in leaves and grains.

Keywords: Tartary buckwheat, hybrid buckwheat, selenium, selenate, UV radiation

Izvleček: Namen dela je bil ugotoviti, kako dodatek selena (Se) in izpostavljenost naravnemu in zmanjšanemu UV sevanju vplivata na tatarsko in hibridno ajdo. Na polju Biotehniške fakultete smo gojili obe vrsti ajde in ju izpostavili štirim različnim obravnavanjem glede na izpostavljenost UV sevanju ter dodani Se (naravno dostopen ali foliarno dodan kot natrijev selenat v koncentraciji 10 mg Se L^{-1}). Merili smo vsebnost barvil (klorofila *a* in *b*, karotenoidov in antocianov) in UV absorbirajočih snovi, stopnjo transpiracije, fotokemično učinkovitost fotosistema II (FS II) in dihalni potencial. Ob koncu poskusa smo določili biomaso posameznih rastlinskih delov. Rezultati so pokazali, da je dodani Se ne glede na vrsto ajde znižal vsebnosti klorofila *a* in karotenoidov, povečal pa je dejansko fotokemično učinkovitost FS II in stopnjo transpiracije. UV sevanje je povečalo vsebnost antocianov. Se in UV sevanje kot samostojna dejavnika nista imela vpliva na pridelek ajde. Hibridna ajda je imela večjo fiziološko aktivnost od tatarske, a manjšo biomaso rastlinskih delov, vključno z manjšim pridelkom. Naravno UV je sevanje na hibridno ajdo delovalo nekoliko negativno, na tatarsko ajdo pa ni imelo opaznega negativnega vpliva. S selenom tretirani tatarska in hibridna ajda sta bili, kar se tiče vsebnosti Se v listih in zrnih, primerni za uporabo v prehrani ljudi in živali.

Ključne besede: Tatarska ajda, hibridna ajda, selen, selenat, UV sevanje

Introduction

Selenium (Se) is essential micronutrient for human and animals. The lack of selenium in human diet can cause severe health problems, while in high concentrations it is toxic (White 2016). In Slovenia Se level in the soil is low (Pirc and Šajn 1997, Kolenc 2013) and consequently, there is a lack of Se in crops. Therefore, an alternative is the addition of Se to the eatable plants that are capable to incorporate anorganic forms of Se in their biomass (Germ et al. 2007). Essentiality of Se for plants has not been proven, but several studies show positive effect of Se addition on plant growth and production (Xue et al. 2001).

Se has been reported to play important protective roles for plants exposed to different environmental constraints, such as drought, salt, low or high temperatures and UV radiation (Kuznetsov et al. 2003, Germ et al. 2007, Djanaguiraman et al. 2010, Yao et al. 2010, Nawaz et al. 2015).

Buckwheat is a plant which can successfully grow in environmental conditions (high UV radiation, drought) which are less suitable for growth of many other crops (Bonafaccia et al. 2003). Researchers believe that, in the face of rapid climate change, especially the increase in UV radiation, it could become an alternative crop, as it is an important source of antioxidants in human nutrition (Fabjan et al. 2003, Kreft et al. 2006). Tartary buckwheat (*Fagopyrum tataricum* Gaertn.) is a nutrient rich plant and has a lot of positive effects on human health (Wieslander et al. 2012). Tartary buckwheat grain is a good source of vitamins B1, B2 and B6 and proteins with high biological value (Bonafaccia et al. 2003). It also has relatively high crude fiber content, and even more rutin and other phenolic compounds than common buckwheat (Fabjan et al. 2003). Hybrid buckwheat (*Fagopyrum hybridum*) is a new buckwheat taxon that was recently obtained by the interspecific crossing of *Fagopyrum tataricum* (4x = 32) × *Fagopyrum giganteum* (Fesenko and Fesenko 2010), although little is known about its properties (Golob et al. 2016, Golob et al. 2018).

The present study aimed to investigate the influence of Se addition, UV radiation and combination of Se treatment and UV radiation on selected biochemical and physiological parameters, biomass and accumulation of Se in Tartary and hybrid buckwheat.

Materials and methods

Tartary buckwheat (*Fagopyrum tataricum*) and hybrid buckwheat (*F. hybridum*) were grown outdoors in an experimental field in Ljubljana. Experiment was designed in four blocks. Each block was divided into eight plots (each, 0.75 m × 1.0 m), one for each treatment and for each buckwheat species. Each block was covered with two different types of panels. The first panel was transparent to UV and visible radiation, thus transmitting wavelengths from 290 nm and above (UV_{amb}), and the second panel was transparent only to the visible region of the spectra, and not for the UV region (UV–), with transmission of wavelengths >380 nm. At the beginning of flowering, half of the experimental plants under each tip of panels, had the foliage treatment with a solution of sodium selenate in concentration 10 mg Se L^{-1} (Se+), with the other half of the plants were treated only with water (Se0). Two weeks after the Se treatments, three plant specimen from each plot (subsamples) out of the four plots for each treatment were used for morphological, anatomical, biochemical and physiological analyses. At the end of the experiment, the plants were harvested, weighed and the plant parts were air dried and lyophilised (Christ Alpha freeze dryer), then homogenised in an agate planar micromill, and used for analysis of the Se contents.

The contents of chlorophyll (Chl *a*, *b*) and carotenoid were determined according to Lichtentaler and Buschman (2001a, b) and measured with a UV/Vis spectrometer. The anthocyanin contents were determined according to Drumm and Mohr (1978). The contents of UV-A and UV-B absorbing compounds were evaluated according to Caldwell (1968).

The potential and effective photochemical efficiency of photosystem (PS) II were evaluated according to Schreiber et al. (1996) using a fluorometer (PAM 2500 Portable Chlorophyll Fluorometer; Heinz Walz GmbH, Germany). The transpiration rate was measured using a steady-state leaf porometer (Decagon Devices, Inc. Pullman, WA, USA). The respiratory potential of the mitochondria was determined as described by Kenner and Ahmed (1975). Preparation of leaf tissue and extraction process is described by Germ et al. (2005).

The total Se content was determined using hydride generation atomic fluorescence spectrometry. Here, 0.2 g of sample was weighed out in a Teflon tube. Digestion of the samples was carried out in the closed tubes, with a mixture of H_2SO_4, HNO_3, H_2O_2 and V_2O_5. HF was added only to the samples that contained fibres. Afterwards, reduction of Se(VI) to Se(IV) was carried out by the addition of concentrated HCl and with heating to 90 ºC for 10 min. After digestion and reduction of the samples, they were diluted with Milli-Q water, and Se was determined using hydride generation atomic fluorescence spectrometry. Each sample was analysed as two replicates. Details of the method of digestion and optimal measurement conditions were described by Smrkolj and Stibilj (2004). The accuracy of the method was validated with the use of certified reference material 'Spinach Leaves' (NIST 1570a).

The normal distribution of the data was tested using Shapiro-Wilk tests and the homogeneity of variance was assessed using Levene's test. For statistical analysis of the data, multivariate analysis of variance was used. The dependent variable was compared with three independent variables: selenium (Se) treatment (Se0 and Se+), UV radiation (UV- and UV_{amb}), species (S)of buckwheat (T and H) and combinations Se×UV, Se×S, UV×S. Differences between treatments were tested using one-way analysis of variance followed by Duncan post-hoc tests. The level of significance was accepted at $p < 0.05$. The SPSS Statistics software, version 20.0 (IBM) was used for the calculations.

Results

Results of multivariate analysis of variance showed that Se addition influenced effective photochemical efficiency of PS II, transpiration rate and content of chlorophyll *a* and carotenoids. UV radiation influenced only content of anthocyanins in leaves. Content of protective substances (anthocyanins, UVA-absorbing compounds and UVB-absorbing compounds), effective photochemical efficiency of PS II and transpiration rate differed between both species (Tab. 1).

Results showed that addition of Se decreased content of chlorophyll *a* and carotenoids content in leaves. On the other hands, Se addition increased effective photochemical efficiency of PS II and transpiration rate (Fig.1).

The plants grown under reduced UV-B radiation had a significantly lower content of anthocyanins than those who were grown in conditions of ambient UV radiation (Fig. 2).

Content of UV-B and UV-A absorbing compounds and content of anthocyanins were higher in Tartary buckwheat comparing to hybrid buckwheat. Hybrid buckwheat had higher transpiration rate and effective photochemical efficiency of PS II than Tartary buckwheat (Fig. 3).

The interaction of buckwheat species and UV radiation conditions was significant for the content of anthocyanins and grain biomass per plant. Tartary buckwheat plants produced a significantly higher amount of anthocyanins under ambient UV radiation than under the reduced UV radiation, while for hybrid buckwheat the anthocyanin content did not differ between UV treatments (Fig. 4a). Similarly Tartary buckwheat plants produced higher grain biomass when grew under ambient UV radiation comparing to reduced UV radiation, while in hybrid buckwheat we observed oposite trend (Fig. 4b).

Table 1: Results of multivariate analysis of variance for evaluation of impact of selenium treatment (Se), UV radiation (UV), buckwheat species (species) and interaction between the observed impacts (Se×UV, Se×species and UV×species) on measured parameters.

Tabela 1: Rezultati multivariatne analize variance za ovrednotenje vpliva dodajanja selena (Se), UV sevanja (UV), vrste ajde (vrsta) ter interakcije med posameznimi vplivi (Se×UV, Se×vrsta in UV×vrsta) na merjene lastnosti

	Independent variable			**Combinations**		
Parameter	**Se**	**UV**	**species**	**Se×UV**	**Se×species**	**UV×species**
Chlorophyll *a*	**0.0293***	0.2943	0.3908	0.8870	0.6799	0.6281
Chlorophyll *b*	0.7830	0.9930	0.9218	0.3005	0.6261	0.5769
Carotenoids	**0.0058***	0.5964	0.3672	0.7003	0.9320	0.5419
Antocyanins	0.6690	**0.0399***	**0.0133***	0.9324	0.9662	**0.0483***
UV-B abs. compounds	0.2559	0.1101	**0.0172***	0.3221	0.7394	0.1302
UV-A abs. compounds	0.2433	0.1189	**0.0010***	0.7014	0.5997	0.1999
ETS activity	0.2493	0.2614	0.7035	**0.0021***	0.3468	0.3288
F_v/F_m	0.3228	0.0914	0.3855	0.9541	0.6923	0.8736
$\Delta F/F_m$’	**0.0411***	0.4742	**0.0013***	0.2449	0.1356	0.4074
Transpiration	**0.0015***	0.1231	**0.0011***	0.7636	0.2682	0.9102
Biomass of grains	0.4965	0.1275	**0.0014***	0.8641	0.1904	**0.0401***

* Statistically significant ($p<0.05$) influence of factor on selected variable is shown in bold.

* Statistično značilen ($p<0,05$) vpliv dejavnika na izbrano lastnost je poudarjen.

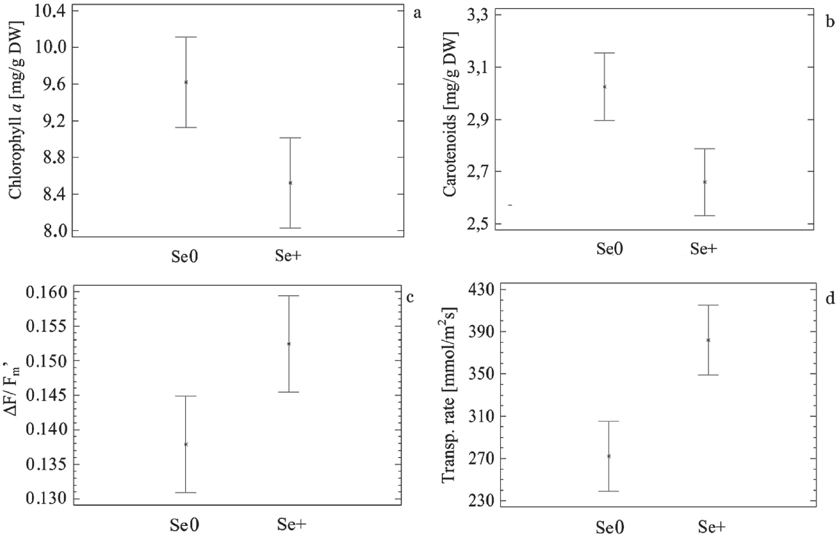

Figure 1: Impact of Se treatment on (a) content of chlorophyll *a*, (b) content of carotenoids, (c) effective photochemical efficiency of PS II ($\Delta F/F_m$’) and (d) transpiration rate (transp. rate). Data are means ± standard deviation (n = 4 for each treatment).

Slika 1: Vpliv dodajanja Se na (a) vsebnost klorofila *a,* (b) količino karotenoidov, (c) dejansko fotokemično učinkovitost FS II ($\Delta F/F_m$’) in (d) transpiracijo (transp. rate). Podatki so predstavljeni kot povprečja ± standardni odklon (n = 4 za vsak tretma).

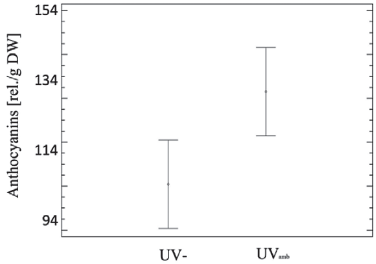

Figure 2: Impact of UV radiation on content of anthocyanins in buckwheat leaves. Data are means ± standard error (n = 4 for each treatment).

Slika 2: Vpliv UV sevanja na vsebnost antocianov v listih obeh vrst ajde. Podatki so predstavljeni kot povprečja ± standardna napaka (n = 4 za vsak tretma).

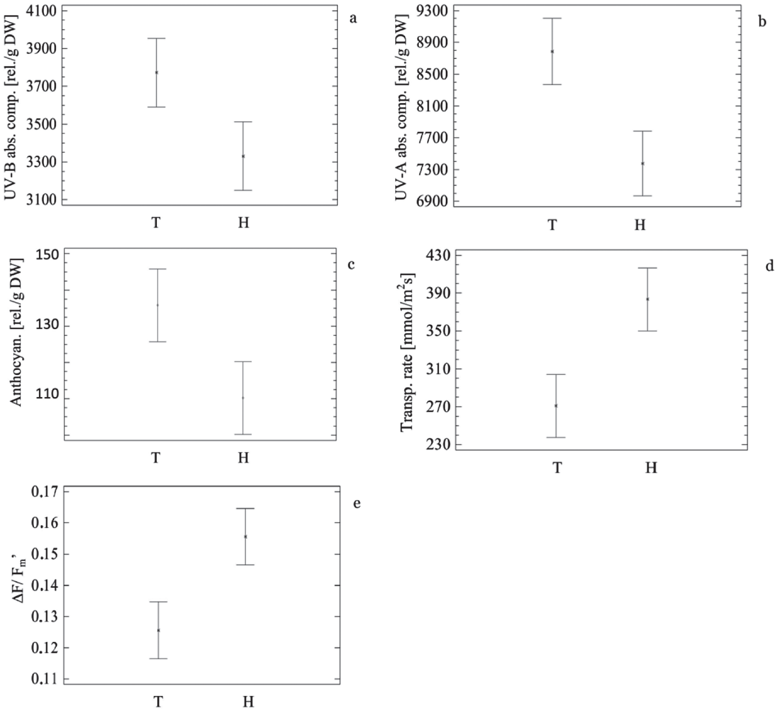

Figure 3: Significant difference in content of (a) UV-B and (b) UV-A absorbing compounds, (c) content of anthocyanins, (d) transpiration rate (transp. rate) and (e) effective photochemical efficiency of PS II ($\Delta F/F_m$') between Tartary and hybrid buckwheat. Data are means ± standard deviation (n = 4 for each treatment).

Slika 3: Značilne razlike v vsebnosti (a) UV-B in (b) UV-A absorbirajočih snovi, (c) v vsebnosti antocianov , (d) transpiraciji in (e) dejanski fotokemični učinkovitosti FS II med tatarsko in hibridno ajdo. Podatki so predstavljeni kot povprečja ± standardni odklon (n = 4 za vsak tretma).

If we compared all treated groups (Se0UV-, Se0UV$_{amb}$, Se+UV-, Se+UV$_{amb}$), we observed that Se+UV$_{amb}$ treated plants had significantly higher biomass of grains per plant than plant from Se+UV- and Se0UV-. There were no statistically significant differences in grain biomass in different treatments of hybrid buckwheat. On the contrary to Tartary buckwheat, Se+UV$_{amb}$ treated hybrid buckwheat had lower grain biomass (but not significantly) than hybrid buckwheat from other treatments (Fig. 5).

The interaction of Se treatment and UV radiation was significant for the respiratory potential measured as electron transport system (ETS) activity. In plants, grown under ambient UV radiation, Se treatment significantly increased ETS activity, while in plants, grown under reduced UV radiation, Se treatment decreased ETS activity (Fig. 6).

Analysis of Se content in stems, leaves and seeds showed that foliar spraying with Se significantly increase contents of Se in all plant parts. Concentrations of Se were the highest in leaves and grains. There were no significant differences in Se content between buckwheat's species (Tab. 2).

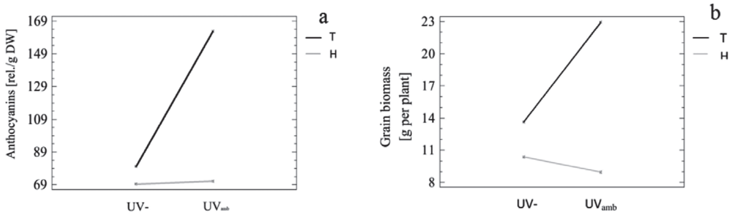

Figure 4: Effect of combination of buckwheat species and UV radiation conditions to (a) anthocyanin content and (b) grain biomass per plant.

Slika 4: Vpliv interakcije med vrsto ajde in UV sevanjem na (a) količino antocianov in (b) biomaso semen na rastlino.

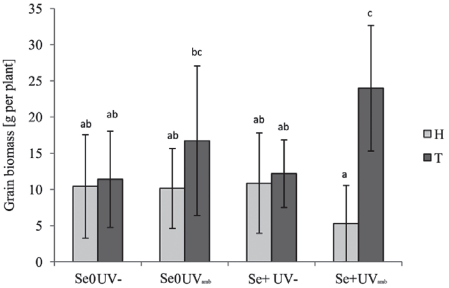

Figure 5: Grain biomass of Tartary buckwheat (T) and hybrid buckwheat (H) grown under different treatments. Data are means ± standard deviation (n = 4 for each treatment). Different letters indicate statistically significant differences.

Slika 5: Biomasa zrn tatarske (T) in hibridne ajde (H), gojenih v različnih razmerah. Podatki so predstavljeni kot povprečja ± standardni odklon (n = 4 za vsak tretma). Različne črke prikazujejo statistično značilne razlike.

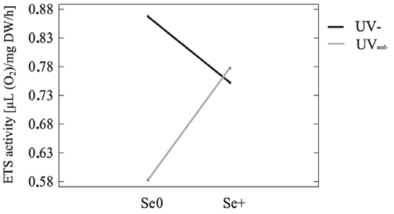

Figure 6: Effect of combination of Se treatment (Se0, Se+) and UV radiation (UV-, UV_{amb}) on the activity of electron transport system (ETS).

Slika 6: Vpliv interakcije med tretiranjem s Se (Se0, Se+) in UV sevanjem (UV-, UV_{amb}) na aktivnost elektronskega transportnega sistema (ETS).

Table 2: Content of Se (ng/g DW) in leaves, seeds and stems of Tartary buckwheat and hybrid buckwheat from different treatments.

Tabela 2: Vsebnost Se (ng/g SM) v listih, semenih in steblih tatarske in hibridne ajde, gojene v različnih razmerah.

	Tartary buckwheat			Hybrid buckwheat		
	seeds	**leaves**	**stems**	**seeds**	**leaves**	**stems**
Se0 UV_{amb}	28 ± 3^a	57 ± 4^a	14 ± 3^a	33 ± 1^a	67 ± 8^a	15 ± 3^a
Se0 UV-	37 ± 8^a	58 ± 7^a	18 ± 1^a	20 ± 2^a	59 ± 4^a	20 ± 3^a
Se+ UV_{amb}	335 ± 86^b	466 ± 69^b	144 ± 36^b	553 ± 109^b	389 ± 58^b	152 ± 30^b
Se+ UV-	616 ± 140^b	678 ± 159^b	245 ± 61^b	616 ± 157^b	475 ± 99^b	207 ± 43^b

Data are means ± standard error (n = 4 for each treatment). Different letters indicate statistically significant differences.

Podatki so predstavljeni kot povprečja ± standardna napaka (n = 4 za vsak tretma). Različne črke predstavljajo statistično značilne razlike.

There was a trend of decreased Se content in Se treated Tartary and hybrid buckwheat grown under ambient UV radiation comparing to plant grown under reduced UV radiation, but due to high variability of results the differences were not statistically significant (Tab. 2).

Discussion

In the present study foliar treatment with Se in concentration of 10 mg L^{-1} in plants significantly decreased content of chlorophyll *a* and carotenoids and increased effective photochemical efficiency of PS II and transpiration rate regardless of buckwheat species and UV radiation condition (Fig. 1). Similarly Xue et al. (2001) report about decreased concentration of chlorophyll in lettuce grown in Se enriched soils. On the other hand Nawaz et al. (2016), in the study with maize, observe increase in total chlorophyll content in plant, foliarly treated with Se. As reported by Breznik et al. (2005), the addition of selenate reduce the chlorophyll *a* content and increase the effective photochemical efficiency of the PS II in Tartary buckwheat. In the study of Padmaja et al. (1989) Se inhibited porphobilinogen synthase activity and decreased total chlorophyll content in light grown mung bean seedlings. The dose dependent response of porphobilinogen synthase activity and chlorophyll content to selenium suggested the possible role of this enzyme in chlorophyll biosynthesis. In buckwheat sprouts, grown from seeds previously soaked in solution of sodium selenate, Se treatment did not influenced content of chlorophyll *a* and carotenoids (Germ et al 2015). Increased effective photochemical efficiency of the PS II as well as transpiration rate in plants indicated increased photosynthetic activity of Se treated buckwheat despite slight decrease of chlorophyll *a* in the present study.

The influence of ambient UV radiation compared to reduced UV radiation on the biochemical and physiological parameters of buckwheat species was small. Ambient UV radiation increased only anthocyanins content in buckwheat leaves (Fig. 2). That was expected, since absorption of the excess photons at high radiation is one of the important functions of anthocyanins in plants (Gould 2004).

Hybrid and Tartary buckwheat significantly differed in some biochemical and physiological parameters. Hybrid buckwheat compared to Tartary buckwheat had a higher content of chlorophyll *a* and *b* and carotenoids as well as higher respiratory potential measured with electron transport system (ETS) activity, transpiration rate and effective photochemical efficacy of PS II regardless Se treatment and UV radiation (Fig. 3). All that indicated that hybrid buckwheat had higher photosynthetic activity. Higher ETS activity in Se treated hybrid in comparison to Se treated Tartary buckwheat observed also Golob et al. 2016. On the other hand, Tartary buckwheat had higher content of anthocyanins and UV-B and UV-A absorbing substances comparing to hybrid buckwheat (Fig. 3). Anthocyanins and UV absorbing compounds are protective substances with antioxidative effect. Higher content of protective substances is probably a consequence of adaptation to unfavourable environmental conditions, as Tartary buckwheat originates from cooler areas of the eastern Qing Zang Plateau, Chuan Xi Plateau and Yun Gui Plateau at high altitude, often > 1500m above sea level (Chen 2001).

The interaction between the buckwheat species and UV radiation conditions significantly influenced biomass of grains and anthocyanins content in leaves (Fig. 4). UV radiation did not play an essential role in grain biomass and anthocyanins content in hybrid buckwheat plants. We observed that ambient UV radiation slightly decreased grain biomass compared to reduced UV radiation in hybrid buckwheat. On the contrary, in Tartary buckwheat a significantly larger grain yield and higher content of anthocyanins was recorded in plants, grown under ambient UV radiation in comparison to plants, grown under reduced UV radiation. The biggest difference in grain biomass between Tartary and hybrid buckwheat was in plants, growing in the conditions of ambient UV radiation and fertilized with selenium. Under this treatment, Tartary buckwheat reached significantly higher grain yield than hybrid buckwheat. There was a trend of decreased biomass of grains in Se+UV_{amb} treated plants in comparison to other treatments (Fig. 5). Golob et al. (2018) grown hybrid buckwheat in similar conditions (with and without Se treatment and under reduced or ambient UV radiation conditions) and also found out that plants grown under ambient UV radiation and treated with Se reached lower biomass of grains and leaves. On the other hand, present study showed that Tartary buckwheat grown under ambient UV radiation had higher biomass of grains, especially when was treated with Se. This indicated better adaptation of Tartary to UV radiation, possibly due to its place of origin (Chen 2001).

The interaction between Se addition and UV radiation conditions significantly influenced ETS activity in both buckwheat species. Addition of Se increased ETS activity in plants grown under ambient UV radiation and decreased it when plants grew under reduced UV radiation (Fig. 6). Increased respiratory potential could be a sign that Se treatment caused slight stress for plants and increased demand for energy devoted for protection (Germ and Gaberščik 2003). Similarly, as it was observed in our study, found Germ et al. (2005) for pumpkins. Interaction between the added Se and the UV-B radiation did not significantly influence ETS activity, however, there was a tendency that addition of Se increased ETS activity in pumpkins grown under ambient UV-B radiation and lowered it in plants grown under reduced UV-B radiation. Our results were opposite to those obtained by Germ (2006). In this study, Se added to common buckwheat grown under ambient UV radiation reduced respiratory potential and increased it in plants grown under reduced UV radiation.

Se treated Tartary and hybrid buckwheat showed a great ability to accumulate high concentrations of Se in grains and leaves with no visible signs of toxic effect. Se accumulated mostly in edible parts of buckwheat plants which is very important, while grains and leaves are often used for human and animal consumption. There were no differences in Se content in plants between Tartary and hybrid buckwheat (Tab. 2), which is not in agreement with foundlings of Golob et al. (2016), who reported about one third lower concentration of Se in Se treated hybrid buckwheat comparing to Tartary buckwheat. However, they used two-fold higher concentration of Se (20 mg Se L^{-1}) in spraying solution. This study showed that UV radiation did not significantly affected Se accumulation in plant parts of Tartary and hybrid buckwheat. However, we observed a tendency that ambient UV radiation decreased Se accumulation in all plant parts of Se treated Tartary and hybrid buckwheat (Tab. 2). Results are in agreement with Golob et al. (2018), who observed statistically significant decrease of Se accumulation in Se treated hybrid buckwheat grown under ambient UV radiation comparing to hybrid buckwheat grown under reduced UV radiation. However, in hybrid buckwheat plants not treated with Se, they observed opposite effect of UV radiation. UV radiation did not influenced accumulation of Se in grains of foliarly treated wheat (Golob et al. 2017).

Se treatment had positive effect on Tartary and hybrid buckwheat, since it increased photosynthetic activity but did not have significant effect on biomass. Ambient UV radiation had slightly negative effect on hybrid buckwheat. Se treatment increased respiratory potential in plants, grown under ambient radiation conditions, which indicated increased potential for protection against environmental constraints. Results showed that UV radiation exerted no negative effect in Tartary buckwheat and had slightly negative effect on hybrid buckwheat. Se treated Tartary and hybrid buckwheat were safe for human and animal consumption regarding to Se concentrations.

Povzetek

V Sloveniji je vsebnost Se v tleh nizka in posledično je Se malo tudi v kulturnih rastlinah in v prehrani ljudi in živali. Dodajanje Se rastlinam, ki ga v procesu presnove vgradijo v svojo biomaso v organski obliki, je zato primerna alternativa. Številne študije dokazujejo, da ima Se tudi pomembno vlogo pri zmanjševanju negativnih učinkov pri rastlinah zaradi delovanja različnih okoljskih dejavnikov, tudi UV sevanja. Ajda je rastlina, ki lahko akumulira relativno velike količine Se, če ji ga dodajamo. Poleg tega ima ajda visoko biološko vrednost, saj vsebuje tudi velike količine rutina, ki je antioksidant, kakovostne beljakovine, vlaknine, nenasičene maščobne kisline ter vitamine B1, B2 in B6.

Cilj raziskave je bil ugotoviti, kakšen vpliv imata sevanje UV in Se na tatarsko in hibridno ajdo. Na polju Biotehniške fakultete smo po parcelah posejali obe vrsti ajde. Rastline smo izpostavili naravnemu UV sevanju in zmanjšanemu UV sevanju. Polovico rastlin smo foliarno gnojili z raztopino natrijevega selenata (10 mg Se/L), ostala polovica je ostala negnojena. Merili smo vsebnost klorofila *a*, klorofila *b*, karotenoidov, antocianov ter UV-A in UV-B absorbirajočih snovi. Poleg tega smo merili tudi transpiracijo, fotokemično učinkovitost FS II in dihalni potencial s pomočjo meritev aktivnosti ETS. Ob koncu poskusa smo stehtali svežo in suho biomaso rastlin.

Rezultati so pokazali, da je dodajanje Se značilno vplivalo na povišanje dejanske fotokemične učinkovitosti FS II in transpiracije ter znižanje vsebnosti klorofila *a* in karotenoidov. Rezultati so pokazali večjo fotosintezno aktivnost s Se obravnavanih rastlin, medtem ko na biomaso gnojenje ni imelo vpliva. Naravno UV sevanje je značilno vplivalo le na povečanje vsebnosti antocianov. Se in UV sevanje kot samostojna dejavnika nista vplivala na pridelek ajde. Hibridna ajda je imela večjo fiziološko aktivnost od tatarske, a manjšo biomaso rastlinskih delov, vključno z manjšim pridelkom. Naravno UV Sevanje je na hibridno ajdo delovalo nekoliko negativno, na tatarsko ajdo pa ni imelo opaznega negativnega vpliva. S selenom obravnavana tatarska in hibridna ajda sta bili, kar se tiče vsebnosti Se v listih in zrnih, primerni za uporabo v prehrani ljudi in živali.

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References

Bonafaccia, G., Marocchini, M., Kreft, I. 2003. Composition and technological properties of the flour and bran from common and tartary buckwheat. Food Chemistry, 80, 9-15.

Breznik, B., Germ, M., Gaberščik, A., Kreft, I., 2005. Combined effects of elevated UV-B radiation and the addition of selenium on common (*Fagopyrum esculentum* Moench) and Tartary (*Fagopyrum tataricum* (L.) Gaertn.) buckwheat. Photosynthetica, 43(4), 583-589.

Caldwell, M.M., 1968. Solar UV radiation as an ecological factor for alpine plants. Ecological Monographs, 38, 243-268.

Chen, Q.F., 2001. Discussion on the origin of cultivated buckwheat in genus *Fagopirum* (Polygonaceae). The proceeding of the 8th ISB. 206-2013.

Djanaguiraman, M., Prasad, P.V.V., Seppanen, M., 2010. Selenium protects sorghum leaves from oxidative damage under high temperature stress by enhancing antioxidant defence system. Plant Physiology and Biochemistry, 48, 999-1007.

Drumm, H., Mohr, H., 1978. The mode of interaction between blue (UV) light photoreceptor and phytochrome in anthocyanin formation of the sorghum seedling. Photochemistry and Photobiology, 27, 241-248.

Germ, M., 2006. The effect of UV-B radiation and selenium on respiratory potential in common buckwheat (*Fagopyrum esculentum*). Fagopyrum, 23, 91–93.

Germ, M., Gaberščik, A., 2003. Dihalni potencial – kazalnik stresa pri rastlinah. Zbornik Biotehniške fakultete Univerze v Ljubljani. Kmetijstvo 81(2), 335–339.

Germ, M., Kacjan Maršić, N., Turk, J., Pirc, M., Golob, A., Jerše, A., Kroflič, A., Šircelj, H., Stibilj, V., 2015. The effect of different compounds of selenium and iodine on selected biochemical and physiological characteristics in common buckwheat and pumpkin sprouts. Acta Biologica Slovenica, 58(1), 35-44.

Germ, M., Kreft, I., Osvald, J., 2005. Influence of UV-B exclusion and selenium treatment on photochemical efficiency of photosystem II; Yield and respiratory potential in pumpkins (*Cucurbita pepo* L.). Plant Physiology and Biochemistry, 43, 445-448.

Germ, M., Stibilj, V., Kreft, I., 2007. Metabolic importance of selenium for plants. The European Journal of Plant Science and Biotechnology 1(1): 91-97.

Golob, A., Germ, M., Kreft, I., Zelnik, I., Kristan, U., Stibilj, V., 2016. Selenium uptake and Se compounds in Se-treated buckwheat. Acta Botanica Croatica, 75(1), 17-24. doi: 10.1515/botcro-2016-0016.

Golob, A., Stibilj, V., Kreft, I., Vogel-Mikuš, K., Gaberščik, A., Germ, M., 2018. Selenium treatment alters the effects of UV radiation on chemical and production parameters in hybrid buckwheat. Acta Agriculturae Scandinavica B. S. P., 68(1), 5-15.

Golob, A., Kavčič, J., Stibilj, V., Gaberščik, A., Vogel-Mikuš, K., Germ, M., 2017. The effect of selenium and UV radiation on leaf traits and biomass production in *Triticum aestivum* L. Ecotoxicology and Environmental Safety 136, 142-149. doi: 10.1016/j.ecoenv.2016.11.007.

Gould, K.S., 2004. Nature's swiss army knife: the diverse protective roles of anthocyanins in leaves. Journal of Biomedicine and Biotechnology, 5, 314-320.

Fabjan, N., Rode, J., Košir, I.J., Wang, Z., Zhang, Z., Kreft, I., 2003. Tartary buckwheat (*Fagopyrum tataricum* Gaertn.) as a source of dietary rutin and quercitrin. Journal of Agricultural and Food Chemistry, 51, 6452-6455.

Fesenko, N.I., Fesenko, N.N., 2010. *Fagopyrum hybridum*: A process of the new buckwheat crop development. In: Advances in buckwheat research. Proceedings of the 11th International Symposium on Buckwheat, Orel (Russia), 19 - 23. Julij 2010. Zotikov, V.I. and Parakhin, N.V. (eds.). Orel, All-Russia Research Institute of Legumes and Groat Crops, 308-313.

Kreft, I., Fabjan, N., Yasumoto, K., 2006. Rutin content in buckwheat (*Fagopyrum esculentum* Moench) food materials and products. Food Chemistry, 98, 508-512.

Kenner, A.A., Ahmed, S.I., 1975. Measurements of electron transport activities in marine phytoplankton. Marine Biology, 33, 119-127.

Kolenc, T., 2013. Vsebnost selena v semenih poljščin, pridelanih v različnih območjih Slovenije. Diplomsko delo. Ljubljana, Pedagoška fakulteta, Biotehniška fakulteta, Oddelek za biologijo, 68 str.

Kuznetsov, Vas. V., Kholodova, V.P., Kuznetsov, V.V., Yagodin, B.A., 2003. Selenium regulates the water status of plants exposed to drought. Doklady Biological Sciences, 390, 266-268.

Lichtenthaler, H.K., Buschmann, C., 2001a. Extraction of photosynthetic tissues: chlorophylls and carotenoids. Current Protocols in Food Analytical Chemistry, F4.2.1-F4.2.6. John Wiley and Sons Inc., New York.

Lichtenthaler, H.K., Buschmann, C., 2001b. Chlorophylls and carotenoids: measurement and characterisation by UV-VIS. Current Protocols in Food Analytical Chemistry, F4.3.1-F4.3.8. John Wiley and Sons Inc., New York.

Nawaz, F., Ashraf, M.Y., Ahmad, R., Waraich, E.A., Shabbir, R.N., Bukhari, M.A., 2015. Supplemental selenium improves wheat grain yield and quality through alternations in biochemical processes under normal and water deficit. Food Chemistry, 175, 350-357.

Nawaz, F., Naeem, M., Ashraf, M.Y., Tahir, M.N., Zulfiqar, B., Salahuddin, Shabbir, M.R.N., Aslam, M., 2016. Selenium supplementation affects physiological and biochemical processes to improve fodder yield and quality of maize (*Zea mays* L.) under water deficit conditions. Frontiers in Plant Science, 7, 1438.

Padmaja, K., Prasad, D.D.K., Prasad, A.R.K., 1989. Effect of selenium on chlorophyll biosynthesis in mung bean seedlings. Phytochemistry, 28, 3321-3324.

Pirc, S., Šajn, R., 1997. Vloga geokemije v ugotavljanju kemične obremenitve okolja. V: Projekt evropskega leta varstva narave 1995. Kemizacija okolja in življenja. Do katere meje? Slovensko ekološko društvo, Ljubljana, 165-185.

Schreiber, U., Kühl, M., Klimant, I., Reising, H., 1996. Measurement of chlorophyll fluorescence within leaves using modified PAM fluorometer with a fiber-optic microprobe. Photosynthesis research, 47, 103-109.

White, P.J., 2016. Selenium accumulation by plants. Annals of Botany, 117, 217-235.

Wieslander, G., Fabjan, N., Vogrinčič, M., Kreft, I., Vombergar, B., Norbäck, D., 2012. Effects of common and Tartary buckwheat consumption on mucosal symptoms, headache and tiredness: A double-blind crossover intervention study. International Journal of Food, Agriculture and Environment, 10, 107-110.

Xue, T.L., Hartikainen, H., Piironen, V., 2001. Antioxidative and growth-promoting effects of selenium on senescing lettuce. Plant and Soil, 237, 55-61.

Yao, X., Chu, J., Ba, C., 2010. Antioxidant responses of wheat seedlings to exogenous selenium supply under enhanced ultraviolet-B. Biological Trace Element Research, 136, 96-105.