JOURNAL OF AGRICULTURAL AND FOOD CHEMISTRY

J. Agric. Food Chem. **2007,** *55,* 795−798 **795**

Effect of Selenium Foliar Application on Chicory (*Cichorium intybus* L.)

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Leaves of young chicory (*Cichorium intybus* L.) plants were sprayed with selenate (1 mg Se^{VI}/L) to establish the distribution of added selenium (Se) in the heads. Its concentration was analyzed in the outer, intermediate, and innermost leaves of chicory heads. The concentration of Se was about double (43−46 ng Se g^{-1} DM) that in the control (21−24 ng Se g^{-1} DM), indicating that the applied Se was transported from the sprayed leaves to the heads. In cv. Monivip, Se concentration was even throughout the head, but in cv. Anivip, the innermost leaves had a lower concentration of Se. No visual symptoms of Se toxicity appeared on the plants, and the quantum yield of photosystem II showed no indication that Se spraying could be harmful for energy conversion. Se increased the respiratory potential in young plants but not in plants at harvest time.

KEYWORDS: ***Cichorium intybus*; ETS activity; fluorescence; selenate; yield**

INTRODUCTION

Slovenia is one of the European countries, including Austria, Croatia, Slovakia, and Finland, that have a low content of selenium (Se) in the soil (*1*−*6*). Cultivation of plants enriched with Se could be an effective way of producing Se-rich foodstuffs, thereby benefiting health (*7*−*12*). It is known that Se is an essential micronutrient needed to prevent oxidative damage and to support hormone balance in human and animal cells (*13*). Se-altered immunological functions play a role in the prevention of arthritis, atherosclerosis, and specific cancers (*14*). Most cereal crops and fodder plants are reported to absorb Se relatively weakly, even when grown on soils with higher Se contents (*15*). Plants take up Se from the soil primarily as selenate (SeO_4^{2-}) or selenite (SeO_3^{2-}) (*16*). It can play a positive biological role in higher plants (*17*−*20*). Studies on ryegrass and lettuce show that, although Se is harmful for plants in high concentrations (reduction of biomass), it can exert beneficial effects at low concentrations (*17*, *20*). Se has been shown to promote the growth of plants subjected to UV-induced oxidative stress (*21*) and to delay senescence and promote the growth of aging seedlings (*6*, *20*, *21*). Senescence processes are partly delayed due to enhanced antioxidation, which is associated with an increase of glutathione peroxidase (GSH-Px) activity (*17*). This enzyme is particularly active in mitochondria. The general metabolic activity of individual organisms can be assessed from terminal electron transport system (ETS) activity in mitochondria. The higher the values are, the greater the readiness of organisms to overcome sudden environmental changes (*22*, *23*). However, no direct studies have been published on the relationship between respiratory potential and Se addition to the plants.

Common chicory (*Cichorium intybus* L.) is a bushy perennial herb with blue or lavender flowers. Leaves, or heads formed from leaves of chicory, are used as a salad vegetables. In Southern Europe (Italy, Spain, and Slovenia), chicory leaf heads are mainly consumed as a raw salad in winter time, when most vegetables are not available (*24*). With 3400 tons produced in 2004, chicory is second among leafy salad vegetables in Slovenia; lettuce is the most cultivated, followed by endive in third place (*25*). Red-colored chicory cultivars especially are low-cost foods, comparable or superior to other foods in having well-known antioxidant properties (*24*). Chicory grown by aeroponics is known as a possible source of selenium-rich vegetables (*26*). However, it is not known whether chicory, or any other leafy vegetable, could be enriched by Se foliar spraying of young plants and distributed to the edible plant parts. In tea plants, foliar application with selenate significantly increased the Se content in the leaves (*11*).

The purpose of this study was to examine the distribution of Se in the heads of chicory plants sprayed foliarly with Se and to determine whether the mass of chicory is influenced by Se spraying. Additionally, we investigated the effect of Se on the quantum yield of photosystem II (PSII) and respiratory potential of plants. Our hypothesis contends that Se will be transported from the sprayed leaves to the other parts of the plants, while not imposing any negative effect on the plants.

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MATERIALS AND METHODS

Plant Material. Chicory plants (*C. intybus* L., Cichoriaceae) cvs. Anivip (red-colored) and Monivip (green-colored) were grown outdoors

10.1021/jf0629888 CCC: $37.00
Published on Web 01/03/2007

Table 1. Potential (F_v/F_m) and Effective ($\Delta F/F_m'$) Quantum Yields of PSII in Control and Se-Treated Cvs. Anivip and Monivip

cultivar group	week 4	week 14	week 16
	F_v/F_m[a]		
Anivip			
control	0.78 ± 0.05	0.78 ± 0.04	0.79 ± 0.06
SeTreat[b]	0.82 ± 0.01	0.79 ± 0.04	0.81 ± 0.02
Monivip			
control	0.80 ± 0.02	0.81 ± 0.03	0.77 ± 0.05
SeTreat[b]	0.79 ± 0.02	0.77 ± 0.04	0.75 ± 0.05
	$\Delta F/F_m'$[a]		
Anivip			
control	0.20 ± 0.09	0.26 ± 0.05	0.28 ± 0.09
SeTreat[b]	0.27 ± 0.08	0.25 ± 0.08	0.29 ± 0.11
Monivip			
control	0.22 ± 0.07	0.31 ± 0.09	0.26 ± 0.05
SeTreat[b]	0.26 ± 0.09	0.25 ± 0.07	0.27 ± 0.06

[a] Results are presented as means ± standard deviation ($n = 9$). [b] SeTreat, Se-treated plants.

in the experimental field of the Biotechnical Faculty, University of Ljubljana (320 m above sea level, 46°35′N, 14°55′E), Slovenia, on a soil (Order Entisols, Suborder Aquents, Great Group Fluvaquents) containing less than 0.1 mg Se kg^{-1}. The treated and control plants were watered with water containing no detectable Se (i.e., less than 0.5 $\mu g\ L^{-1}$). Plants with about three and four leaves, respectively, were foliarly sprayed twice, namely, 4 and 6 weeks after germination (2 week intervals between two sprayings), with an aqueous solution containing 1 mg Se L^{-1} in the form of sodium selenate to give 2 μg Se per plant. Plants were planted in a split plot design, in three repeats, 20 plants per treatment and per repeat. In week 19 after germination, plants were harvested and the parts were separated. Heads were removed from the rest of the plant and rinsed with water before selenium determination; the oldest leaves (at least six) not forming the head were weighed, together with the other nonutilizable remainder.

Determination of the Se Concentration. Se was determined in the end of week 19 after germination, in freeze-dried samples of the outer, intermediate, and innermost leaves of the heads in three independent samples composed of three plants each, using hydride generation atomic fluorescence spectrometry (HG-AFS) (*27*). To 0.150−0.200 g of sample, 0.5 mL of concentrated H_2SO_4 and 1.5 mL of HNO_3 were added and heated in a closed tube for 60 min at 130 °C in an aluminum block. Two times 2 mL of H_2O_2 were added and heated for 15 min at 115 °C after each addition. The solution was then cooled to room temperature, 0.1 mL of V_2O_5 in H_2SO_4 was added, and the tube was heated at 115 °C for 20 min. A 2.5 mL amount of concentrated HCl was added and heated at 100 °C for 10 min to reduce Se^{VI} to Se^{IV}. Samples were diluted to an appropriate volume (around 3 ng Se g^{-1}), and Se was detected by HG-AFS.

Chlorophyll Fluorescence Measurements. Fluorescence was measured in the outer leaves 2 days after the first foliar spraying with Se (in week 4 after germination), then in weeks 14 and 16. The photochemical quantum yield of PSII was measured using a fluorometer OS-500 (Opti-Sciences, Tyngsboro, MA). The ratio ($F_m - F_o/F_m = F_v/F_m$) is a measure of the potential maximal PSII quantum yield. For dark adaptation, plants were kept in cuvettes for 15 min followed by measurement of F_v/F_m at ambient temperature. Fluorescence was excited with a saturating beam of "white light" [photosynthetic photon flux density (PPFD) = 8000 $\mu mol\ m^{-2}\ s^{-1}$, 0.8 s]. Effective quantum yield was determined by providing a saturating pulse of white light (PPFD = 9000 $\mu mol\ m^{-2}\ s^{-1}$, 0.8 s) to the leaf using a standard 60° angle clip. The effective quantum yield of PSII provided an estimate of the actual efficiency of energy conversion in PSII and was defined as $(F_m' - F)/F_m' = \Delta F/F_m'$. F_m' was the maximal fluorescence of an illuminated sample, and F was the steady-state fluorescence (*28*). The effective quantum yield of PSII was measured under saturating PPFD (1800 $\mu mol\ m^{-2}\ s^{-1}$) at ambient temperature.

ETS Activity. Respiratory potential was measured as terminal ETS activity of mitochondria, as described by Packard (*29*). ETS activity was measured 2 days after the first foliar spraying with Se (in week 4 after germination), then in weeks 14, 16, and 19, in the outer leaves. Leaves were weighed and homogenized for enzyme analysis in cold homogenizing buffer, 0.1 M sodium phosphate pH 8.4, containing 0.15% (w/v) polyvinyl pyrrolidone, 75 μM $MgSO_4$, and 0.2% (v/v) Triton-X-100, in a mortar and with an ultrasound homogenizer (4710; Cole-Parmer, Vernon Hills, IL) and then centrifuged (8500 Hz, 0 °C, 4 min) in a top-refrigerated ultracentrifuge (2K15, Sigma, Osterode, Germany). A 0.5 mL amount of the supernatant was mixed with the 1.5 mL of substrate solution [0.1 M sodium phosphate buffer (pH 8.4), 1.7 mM NADH, 0.25 mM NADPH, and 0.2% (v/v) Triton-X-100] and 0.5 mL of INT (20 mg of 2-*p*-iodo-phenyl 3-*p*-nitrophenyl 5-phenyl tetrazolium chloride in 10 mL of bidistilled water). The mixture was incubated at 20 °C for 40 min. After the reaction was stopped with stopping solution (formaldehyde and phosphoric acid, 1:1), the formazan absorbance at 490 nm was determined with a UV/vis Spectrometer System (Lambda 12, Perkin-Elmer, Norwalk, CT). The ETS activity was calculated as the rate of INT reduction, which was converted to the amount of oxygen utilized per dry mass (DM) of the leaf per unit time, as described by Kenner and Ahmed (*30*).

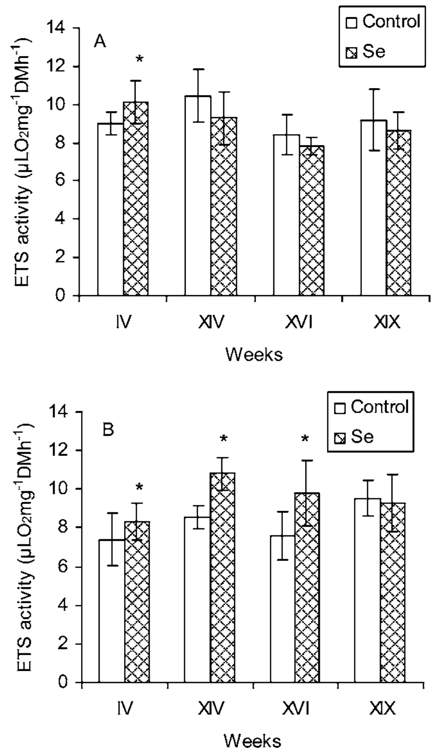

Figure 1. Terminal ETS activity in control and Se-treated cvs. Anivip (**A**) and Monivip (**B**), expressed on a DM basis. An asterisk indicates values significantly different from the controls at $P < 0.05$. Results are presented as means ± standard deviation for three independent analyses. Error bars show 95% confidence intervals.

Statistical Analysis. All measurements were carried out on three parallel samples in each repeat. The data were evaluated by multifactor analysis of variance (Statgraphics Version 4), and significance was accepted at $P < 0.05$.

RESULTS AND DISCUSSION

Vitality of Plants. No visual symptoms of Se toxicity appeared on plants. Se did not influence either potential quantum yield (F_v/F_m) or effective quantum yield ($\Delta F/F_m'$) of PSII (**Table 1**). Similar results were obtained for pumpkin leaves (*18*). For a wide variety of dark-adapted plants F_v/F_m values ranged between 0.8 and 0.833 (*28*). Values of F_v/F_m were close to the theoretical maximum, indicating an undamaged antenna complex (*31*). Although the effective quantum yield was lower than the potential quantum yield of PSII, the closeness of the potential

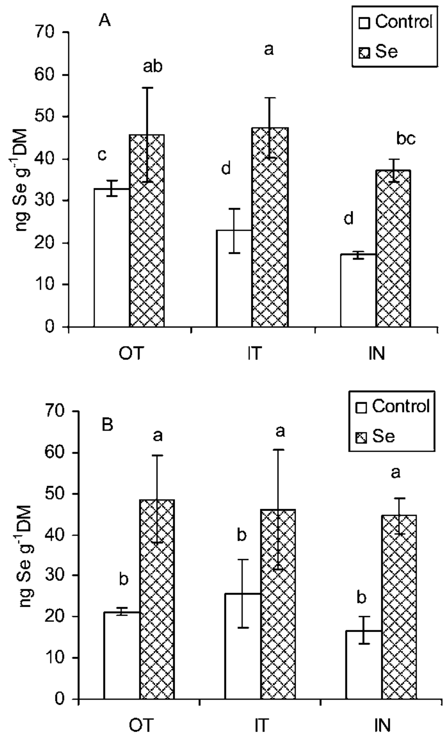

Figure 2. Mass ratio of Se in the outer (OT), intermediate (IT), and innermost (IN) leaves in control and Se-treated cvs. Anivip (**A**) and Monivip (**B**). Values with different letters were significantly different at $P < 0.05$. Results are presented as means ± standard deviation for three independent repeats composed of three plants each. Error bars show 95% confidence intervals.

photochemical efficiency to the theoretical maximum indicated reversible inactivation rather than damage to the reaction center. Se treatment did not affect the potential quantum yield of PSII in common buckwheat (*32*) but was shown to increase it in strawberry (*33*). It increased effective quantum efficiency of PSII in common buckwheat (*32*). In these species, Se exerted a positive role on the photochemistry of PSII.

ETS activity was highest in young Se-treated plants only in cv. Anivip, while later in their development there was no difference between control and Se-treated plants (**Figure 1A**). ETS activity was highest in Se-treated plants and remained so until 16 weeks after germination in cv. Monivip (**Figure 1B**). Assimilation and transport of elements like Se demand an additional supply of energy derived from enhanced respiratory potential. Increased mitochondrial activity in Se-treated plants therefore augmented the energetic cost involved in generating the internal pathways for Se from the outer to the middle leaves. Enhanced mitochondrial activity due to added Se, as presented here, has been known from Sreekala et al. (*34*), when Se was applied to *Trigonella foenum-graecum* seedlings.

Se Distribution in Leaves of the Head. In the heads of plants foliarly sprayed with Se, the concentration of Se was, on average, more than double (2-fold) that in untreated plants in cv. Monivip (**Figure 2B**) and 1.9-fold more in cv. Anivip (**Figure 2A**). Clearly, the sprayed Se was transported from the sprayed leaves to the leaves of the chicory head. In cv. Monivip, Se concentration was uniform throughout the head, while in cv. Anivip the youngest, innermost leaves had a lower concentration of Se, in comparison to the intermediate ones, but still higher than in the control (**Figure 2A**,**B**). Thus, Se-enriched chicory is a potential source of dietary Se, since the foliar-added Se is in all parts of the head. Foliarly sprayed chicory heads

Table 2. DM of the Whole Plants and Heads of Chicory in Control and Se-Treated Cvs. Anivip and Monivip

cultivar	group	mass of the whole plant (g)[a]	mass of the heads (g)[a]
Anivip	control	39.16 ± 4.59	19.63 ± 0.72
	SeTreat[b]	41.70 ± 10.91	21.44 ± 1.10
Monivip	control	34.41 ± 1.97	16.36 ± 1.05
	SeTreat[b]	41.18 ± 0.92c	14.95 ± 0.40

[a] Values are means of three independent repeats for each treatment ± standard deviation ($n = 3$). [b] SeTreat, Se-treated plants. The value followed by the letter "c" was significantly different ($P < 0.05$) from the control.

are a suitable vegetable for growing in localities where the concentration of Se in the soil is low. Foliar application, performed manually only on plants, is the most appropriate way to add Se, since contamination of the soil is minimal. Foliar application to barley at 10 and 20 g Se ha^{-1}, as sodium selenate, increased the Se content of barley grain and straw and red clover forage (*35*). According to our previous study (*18*), we expected a stimulatory effect of Se on the biomass of chicory due to low Se concentration in plants. The total DM of plants was higher in Se-sprayed plants than in controls in cv. Monivip, but in cv. Anivip, there were no significant differences between sprayed and control plants. The mass of heads did not differ between Se-treated plants and controls in either cultivar (**Table 2**). A stimulatory effect of foliar application of Se on growth has been reported for ryegrass (*17*), lettuce (*20*), potato (*36*), and green tea leaves (*11*). Plant growth promoted by Se is the result of increased starch accumulation in chloroplasts (*37*) and diminished lipid peroxidation (*20*).

In summary, the leaves of chicory efficiently take up foliarly sprayed Se, which is afterward transported to the later-formed leaves of the head. Chicory included in the diet can be a possible source of Se intake for human beings. Chicory, including Se-rich chicory heads, has in southern Europe and in other regions, where there is a low content of Se in the soil and where leaf chicory is feasibly grown, the potential as a low price vegetable with a suitable content of Se. There are cultivar differences: Se increases the mass of the plant in cv. Monivip but not in cv. Anivip. Se was not toxic to the plants, measured either by visual signs or by the flow of electrons in PSII. It clearly influenced respiratory activity in chicory plants.

ABBREVIATIONS USED

cv., cultivar; DM, dry mass; ETS, electron transport system; F, the steady-state fluorescence; F_o, minimal chlorophyll *a* fluorescence yield in dark-adapted samples; F_m, maximal chlorophyll *a* fluorescence yield in dark-adapted samples; F_m', maximal chlorophyll *a* fluorescence yield of an illuminated sample; F_v, variable fluorescence; IN, inner; INT, iodo-nitro-tetrazolium-chloride; IT, intermediate; OT, outer; PPFD, photosynthetic photon flux density; PSII, photosystem II; SeTreat, Se-treated plants.

ACKNOWLEDGMENT

We are grateful to Prof. Roger Pain for critical reading of the manuscript. We thank Marko Černe, Dragan Žnidarčič, and Matej Jeraša for technical assistance.

LITERATURE CITED

(1) Kreft, I.; Stibilj, V.; Trkov, Z. Iodine and selenium content in pumpkin (*Cucurbita pepo* L.) oil and oil-cake. *Eur. Food Res. Technol.* **2002**, *215*, 279−281.

(2) Smrkolj, P.; Pograjc, L.; Hlastan-Ribič, C.; Stibilj, V. Selenium content in selected Slovenian foodstuffs and estimated daily intakes of selenium. *Food Chem*. **2005**, *90*, 691−697.
(3) Pfannhauser, W.; Sima, A.; Heumann, S.; Schaller, U.; Wilplinger, M.; Schönsleben, I. Estimation of trace element supply in Austria. In *Metal Ions in Biology and Medicine*; Centeno, J. A., Collery, P., Vernet, G., Finkelman, R. B., Gibb, H., Etienne J. C., Eds.; John Libbey Eurotext: Paris, 2000; pp 521−523.
(4) Klapec, T.; Mandić, M. L.; Grgić, J.; Primorac, Lj.; Ikić, M.; Lovrić, T.; Grgić, Z.; Herceg, Z. Daily dietary intake of selenium in eastern Croatia. *Sci. Total Environ.* **1998**, *217*, 127−136.
(5) Kadrabova, J.; Mandaric, A.; Ginter, E. The selenium content of selected food from the Slovak Republic. *Food Chem*. **1997**, *58*, 29−32.
(6) Hartikainen, H.; Xue, T. The promotive effect of selenium on plant growth as trigged by ultraviolet irradiation. *J. Environ. Qual*. **1999**, *28*, 1272−1275.
(7) Ip, C. P.; Lisk, D. J. Enrichment of selenium in allium vegetables for cancer prevention. *Carcinogenesis* **1994**, *15*, 1881−1885.
(8) Poggi, V.; Pifferi, P. G.; Bordoni, A.; Biagi, P. Plant derived foods supplied with selenium: The potato. *Ind. Aliment.* **1999**, *38*, 1107.
(9) Finley, J. W.; Ip, C.; Lisk, D. J.; Davis, C. D.; Hintze, K. J.; Whanger, P. D. Cancer-protective properties of high-selenium broccoli. *J. Agric. Food Chem.* **2001**, *49*, 2679−2683.
(10) Carvalho, K. M.; Gallardo-Williams, M. T.; Benson, R. F.; Martin, D. F. Effects of selenium supplementation on four agricultural crops. *J. Agric. Food Chem*. **2003**, *51*, 704−709.
(11) Hu, Q. H.; Xu, J.; Pang, G. X. Effect of selenium on the yield and quality of green tea leaves harvested in early spring. *J. Agric. Food Chem.* **2003**, *51*, 3379−3381.
(12) Lyons, G.; Ortiz-Monasterio, I.; Stangoulis, J.; Graham, R. Selenium concentration in wheat grain: Is there sufficient genotypic variation to use in breeding? *Plant Soil* **2005**, *269*, 369−380.
(13) Terry, N.; Zayed, A.; De Souza, M. P.; Tarun, A. S. Selenium in higher plants. *Annu. Rev. Plant Physiol. Plant Mol. Biol*. **2000**, *51*, 401−432.
(14) Duffield-Lillico, A. J.; Dalkin, B. L.; Reid, M. E.; Turnbull, B. W.; Slate, E. H.; Jacobs, E. T.; Marshall, J. R.; Clark, L. C. Selenium supplementation, baseline plasma selenium status and incidence of prostate cancer: an analysis of the complete treatment period of the Nutritional Prevention of Cancer Trial. *BJU Int.* **2003**, *91*, 608−612.
(15) Nowak, J.; Kaklewski, K.; Ligocki, M. Influence of selenium on oxidoreductive enzymes activity in soil and in plants. *Soil Biol. Biochem*. **2004**, *36*, 1553−1558.
(16) Ellis, D. R.; Salt, D. E. Plants, selenium and human health. *Curr. Opin. Plant Biol.* **2003**, *6*, 273−279.
(17) Hartikainen, H.; Xue, T.; Piironen, V. Selenium as an antioxidant and pro-oxidant in ryegrass. *Plant Soil* **2000**, *225*, 193−200.
(18) Germ, M.; Kreft, I.; Osvald, J. Influence of UV-B exclusion and selenium treatment on photochemical efficiency of photosystem II, yield and respiratory potential in pumpkins (*Cucurbita pepo* L.). *Plant Physiol. Biochem*. **2005**, *43*, 445−448.
(19) Shanker, A. K. Countering UV-B stress in plants: Does selenium have a role? *Plant Soil* **2006**, *282*, 21−26.
(20) Xue, T.; Hartikainen, H.; Piironen, V. Antioxidative and growth-promoting effect of selenium in senescing lettuce. *Plant Soil* **2001**, *237*, 55−61.
(21) Xue, T. L.; Hartikainen, H. Association of antioxidative enzymes with the synergistic effect of selenium and UV irradiation in enhancing plant growth. *Agric. Food Sci. Finl.* **2000**, *9*, 177−186.
(22) Packard, T. T. Measurement of electron transport activity of microplankton. In *Advances in Aquatic Microbiology*; Jannasch, H., Williams, P. J. LeB., Eds.; Academic Press Harcourt Brace Jovanovich Publishers: London, Orlando, San Diego, New York, Austin, Montreal, Sydney, Tokyo, Toronto, 1985; pp 207−261.
(23) Bartoli, C. G.; Gomez, F.; Gergoff, G.; Guiamet, J. J.; Puntarulo, S. Up-regulation of the mitochondrial alternative oxidase pathway enhances photosynthetic electron transport under drought conditions. *J. Exp. Bot*. **2005**, *56*, 1269−1276.
(24) Rossetto, M.; Lante, A.; Vanzani, P.; Spettoli, P.; Scarpa, M.; Rigo, A. Red chicories as potent scavengers of highly reactive radicals: A study on their phenolic composition and peroxyl radical trapping capacity and efficiency. *J. Agric. Food Chem.* **2005**, *53*, 8169−8175.
(25) Statistični letopis republike Slovenije 2005, Production of vegetables. In *Statistical Yearbook of the Republic of Slovenia 2005*; Smrekar, T., Ed.; Statistical Office of the Republic of Slovenia: Ljubljana, 2005; pp 298−299.
(26) Mazej, D.; Falnoga, I.; Veber, M.; Stibilj, V. Determination of selenium species in plant leaves by HPLC-UV-HG-AFS. *Talanta (Oxford*) **2006**, *68*, 558−568.
(27) Smrkolj, P.; Stibilj, V. Determination of selenium in vegetables by hydride generation atomic fluorescence spectrometry. *Anal. Chim. Acta* **2004**, *512*, 11−17.
(28) Schreiber, U.; Bilger, W.; Neubauer, C. Chlorophyll fluorescence as a nonintrusive indicator for rapid assessment of in vivo photosynthesis. In *Ecophysiology of Photosynthesis*; Schulze, E. D., Caldwell, M. M., Eds.; Springer-Verlag: Berlin, Heidelberg, New York, 1995; pp 49−69.
(29) Packard, T. T. The measurement of respiratory electron-transport activity in marine phytoplankton. *J. Mar. Res.* **1971**, *29*, 235−243.
(30) Kenner, R. A.; Ahmed, S. I. Measurements of electron transport activities in marine phytoplankton. *Mar. Biol*. **1975**, *33*, 119−127.
(31) Bischof, K.; Hanelt, D.; Wiencke, C. UV-radiation can affect depth-zonation of Antarctic macroalgae. *Mar. Biol. Berlin* **1998**, *131*, 597−605.
(32) Breznik, B.; Germ, M.; Gaberščik, A.; Kreft, I. Combined effects of elevated UV-B radiation and the addition of selenium on common and tartary buckwheat. *Photosynthetica* **2005**, *43*, 583−589.
(33) Valkama, E.; Kivimäenpää, M.; Hartikainen, H.; Wulff, A. The combined effects of enhanced UV-B radiation and selenium on growth, chlorophyll fluorescence and ultrastructure in strawberry (*Fragaria* × *ananassa*) and barley (*Hordeum vulgare*) treated in the field. *Agric. For. Meteorol*. **2003**, *120*, 267−278.
(34) Sreekala, M.; Santosh, T. R.; Lilitha, K. Oxidative stress during selenium deficiency in seedlings of *Trigonella foenum-graecum* and mitigation by mimosine. Part I. Hydroperoxide metabolism. *Biol. Trace Elem. Res.* **1999**, *70*, 193−207.
(35) MacLeod, J. A.; Gupta, U. C.; Milburn, P.; Sanderson, J. B. Selenium concentration in plant material, drainage and surface water as influenced by Se applied to barley foliage in a barley red clover potato rotation. *Can. J. Soil Sci*. **1998**, *78*, 685−688.
(36) Turakainen, M.; Hartikainen, H.; Seppänen, M. M. Effects of selenium treatments on potato (*Solanum tuberosum*) growth and concentrations of soluble sugars and starch. *J. Agric. Food Chem.* **2004**, *25*, 5378−5382.
(37) Pennanen, A.; Xue, T.; Hartikainen, H. Protective role of selenium in plant subjected to severe UV irradiation stress. *J. Appl. Bot*. **2002**, *76*, 66−76.

Received for review October 17, 2006. Revised manuscript received November 25, 2006. Accepted November 28, 2006. This research is a part the project financed by the Slovenian Research Agency (ARRS), Ljubljana: The Effect of Selenium on Crop Plants (J4-6476-0481-04/4.03), through Contract 3311-03-831016; Physiological Indicators of Stress in Cultivated Plants (J4-6428-0105-04/4.03); and Program P4-0085.

JF0629888