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Malnutrition and Crops Biofortification with Selenium and Zinc

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Universita degli Studi di Palermo, May 2025

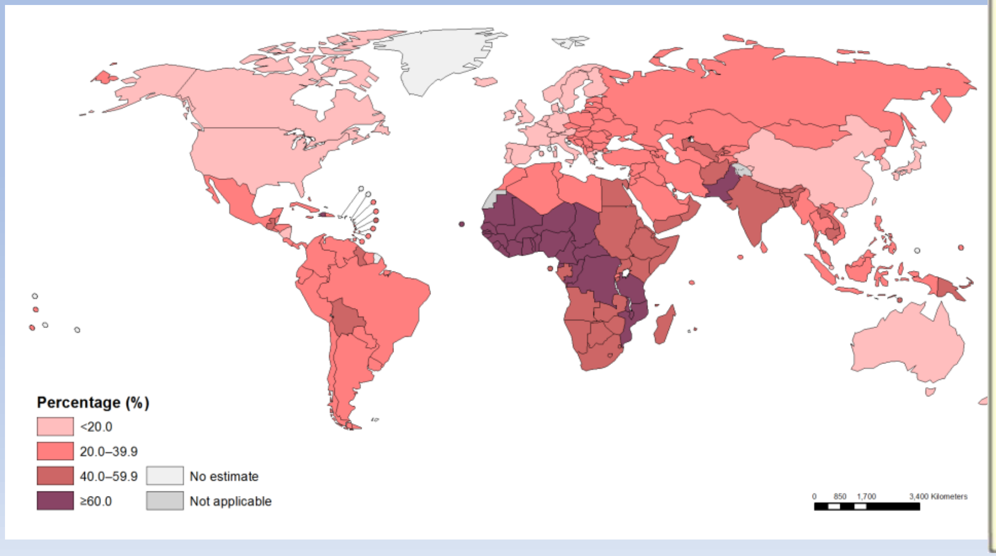
Malnutrition (Undernutrition)

- Micronutrients are necessary for human health, for physical and mental development, for the functioning of the immune system and various metabolic processes.

- Micronutrient malnutrition (hidden hunger) affects almost half of the global population, and interest in it has grown significantly over the last decade due to its potentially large implications for global health.

Undernutrition worldwide

- Malnutrition is not only a problem of poor countries and can exist even when the food supply is adequate in terms of energy needs.



The global anaemia prevalence due to Fe deficiency
(World Health Organization. The global anaemia prevalence in 2011. Geneva (Switzerland); WHO; 2015)

Zinc deficiency worldwide *VFRC Report (2014): Eliminating Zinc Deficiency in Rice-Based Systems*

Undernutrition

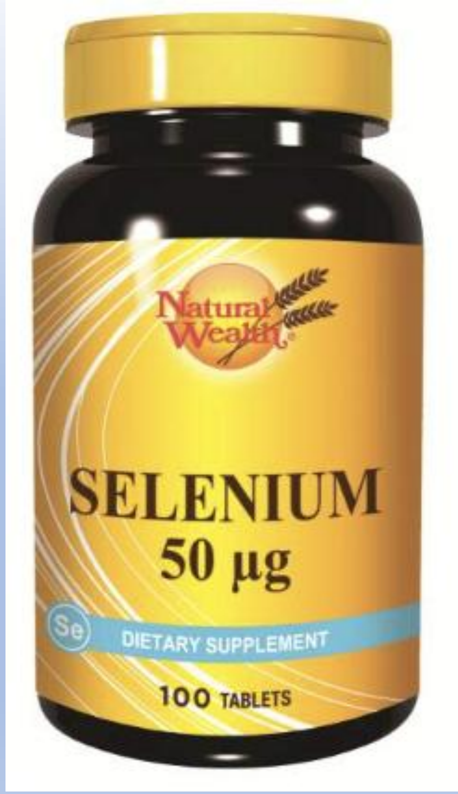
- Iron (Fe) and iodine (I) deficiency are the most significant causes of hidden hunger in developing countries.
- Zinc (Zn) deficiency is also a global malnutrition problem.
- Selenium (Se) deficiencies occur regionally (but include almost all of Europe)

- we can expect malnutrition where cereals are the main source of daily caloric intake but also in regions where agricultural soils are poor in plant-available micronutrients.

What does undernutrition look like?

Zinc is needed for many body processes, including gene expression, enzymatic reactions, protein synthesis, and DNA synthesis

UN Sustainable Development Goal ‘world with zero hunger’ by 2030



189 results from Web of Science Core Collection for:

COVID (Topic) and **Zinc** (Topic) and **Selenium** (Topic)

379 results from Web of Science Core Collection for:

COVID (Topic) and **Selenium** (Topic)

1,224 results from Web of Science Core Collection for:

COVID (Topic) and **Zinc** (Topic)

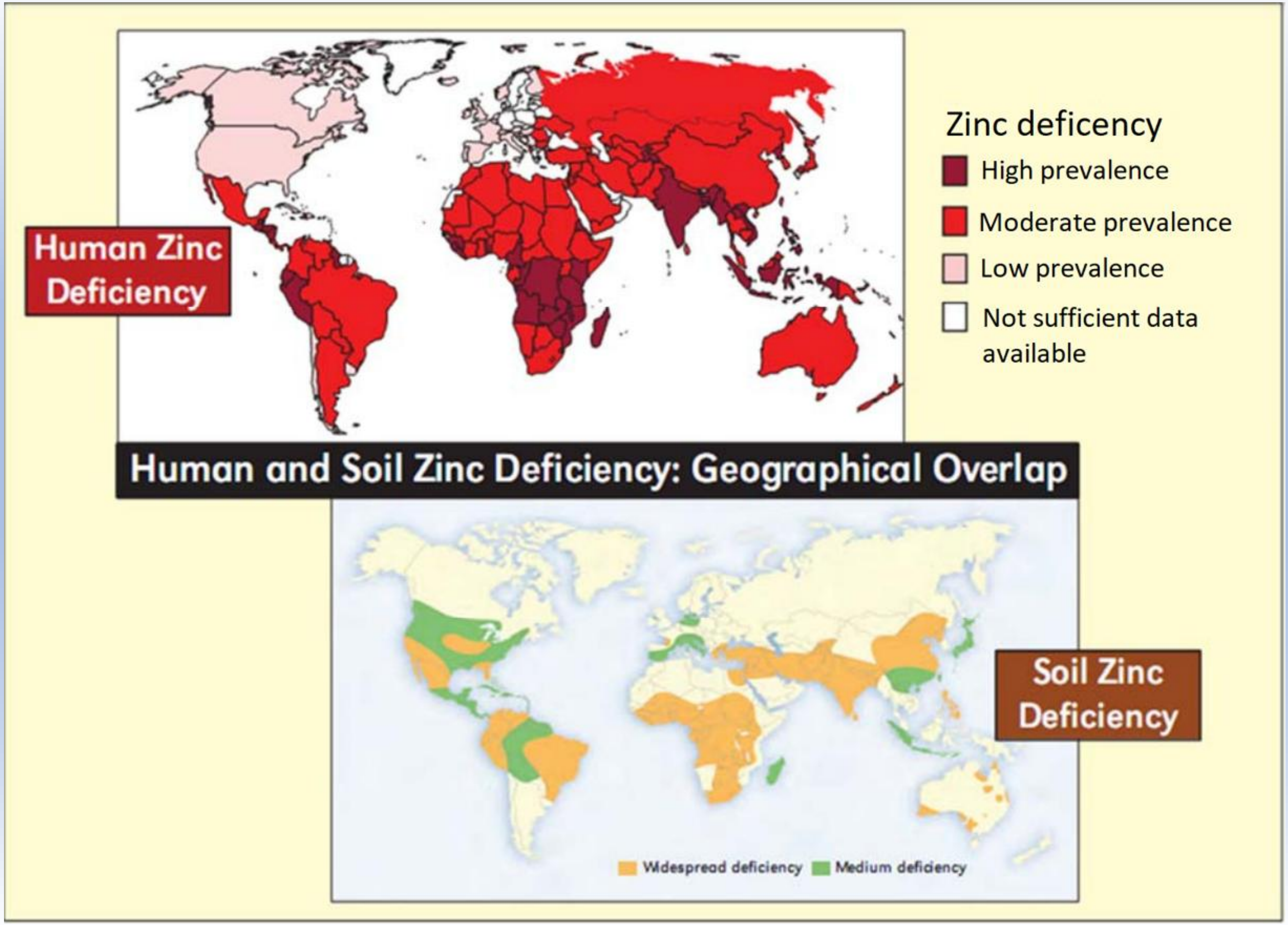
ORIGINAL RESEARCH article

Front. Immunol., 28 November 2022

Sec. Nutritional Immunology

Volume 13 - 2022 | https://doi.org/10.3389/fimmu.2022.1022673

Association of COVID-19 mortality with serum selenium, zinc and copper: Six observational studies across Europe

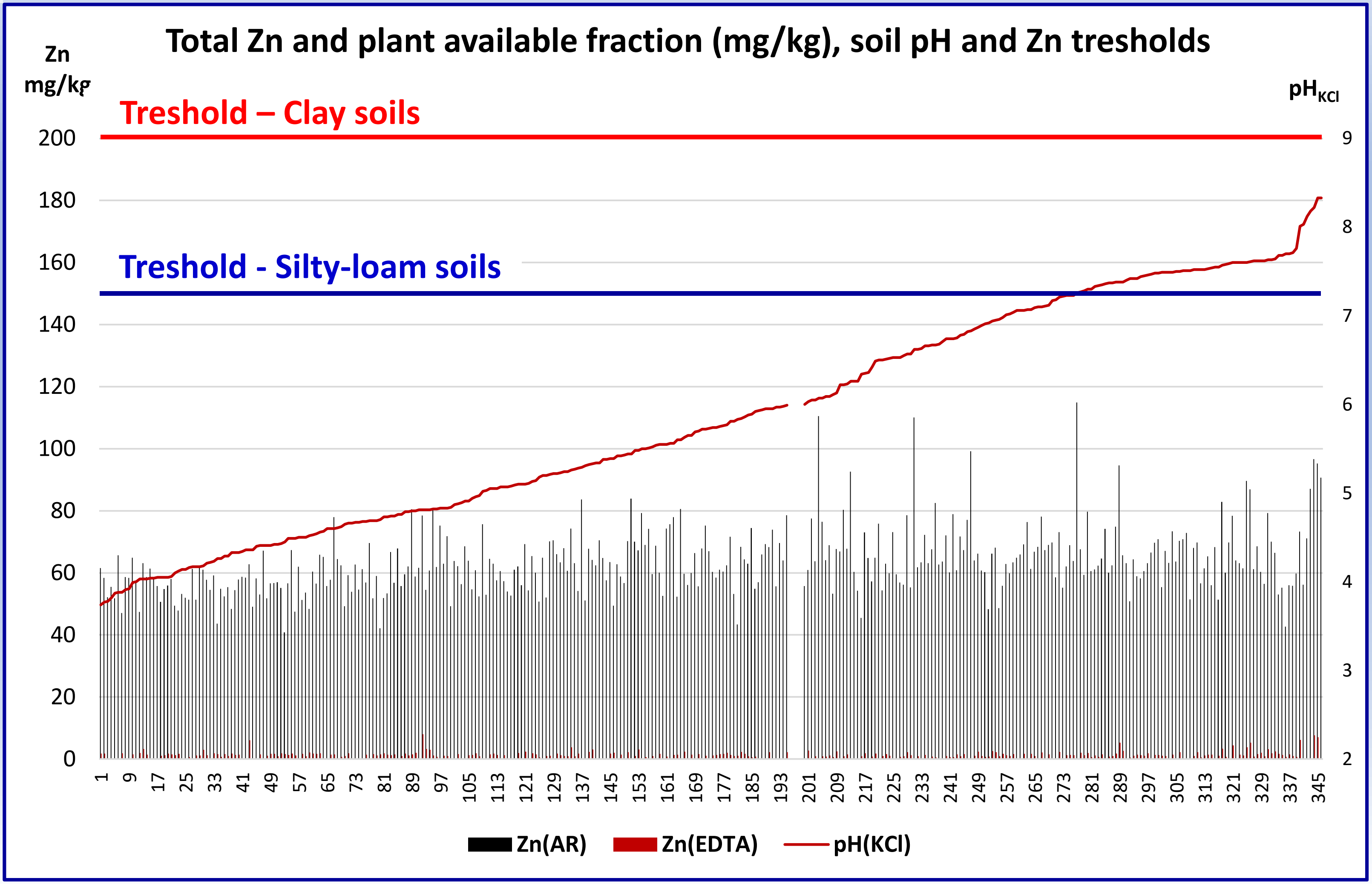


Soil Zn deficiency

Regions with Zn deficiency in the soil

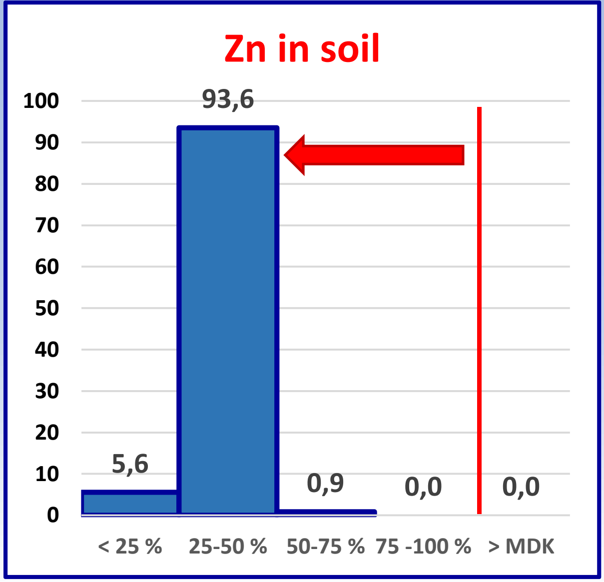
VFRC Report (2014): Eliminating Zinc Deficiency in Rice-Based Systems

Total Zn in soils in the Pannonian part of Croatia

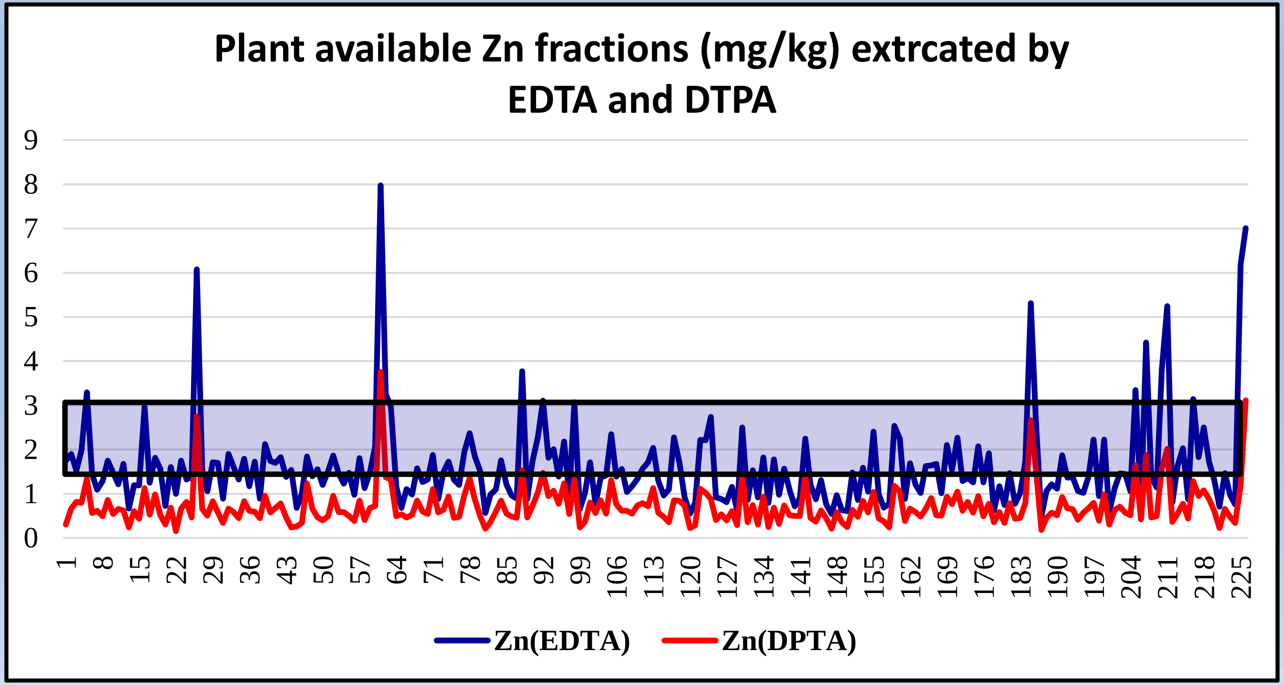


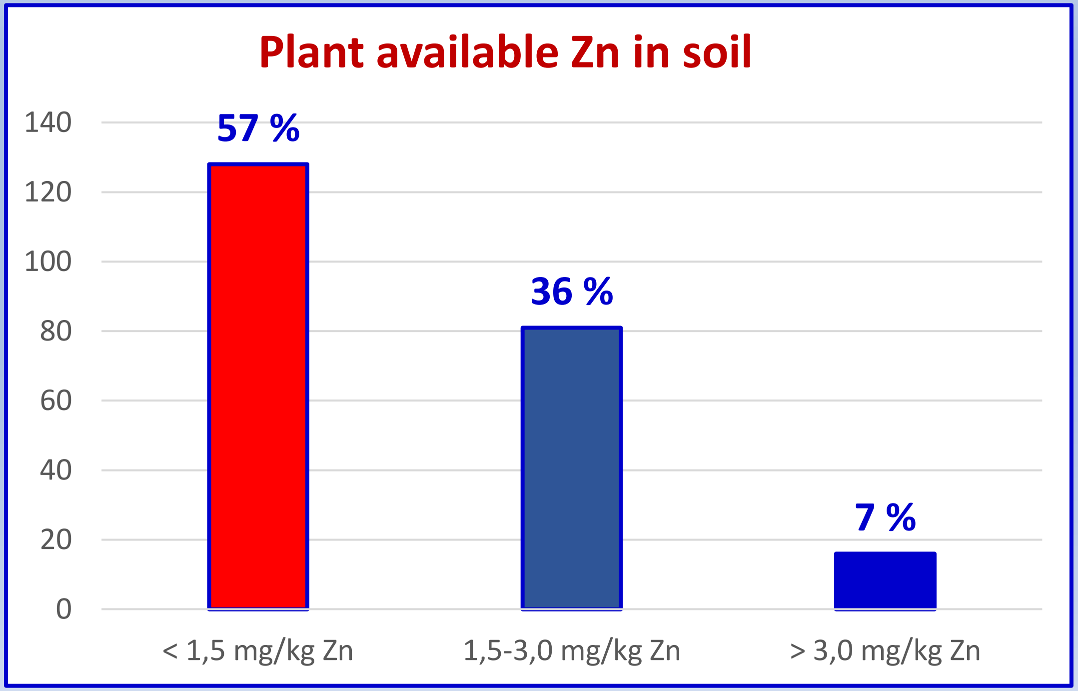
Concentration of total Zn in the soils of eastern Croatia

Lončarić i Haman. (2015.): Doprinos poljoprivrede čistom okolišu i zdravoj hrani.

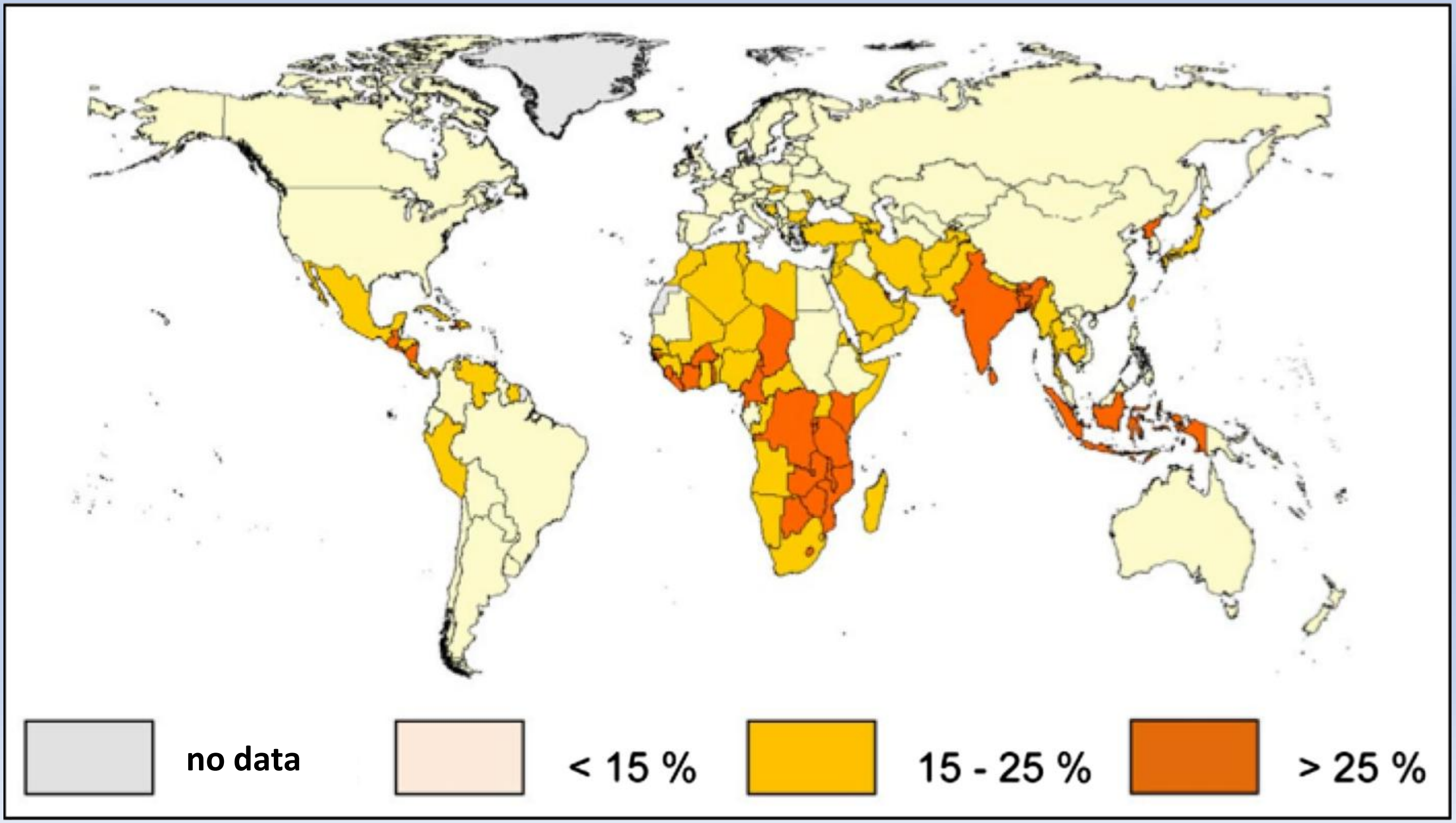


Available Zn in the soils of eastern Croatia is mostly at the level of low availability





Zinc undernutrition in Croatia & Italy



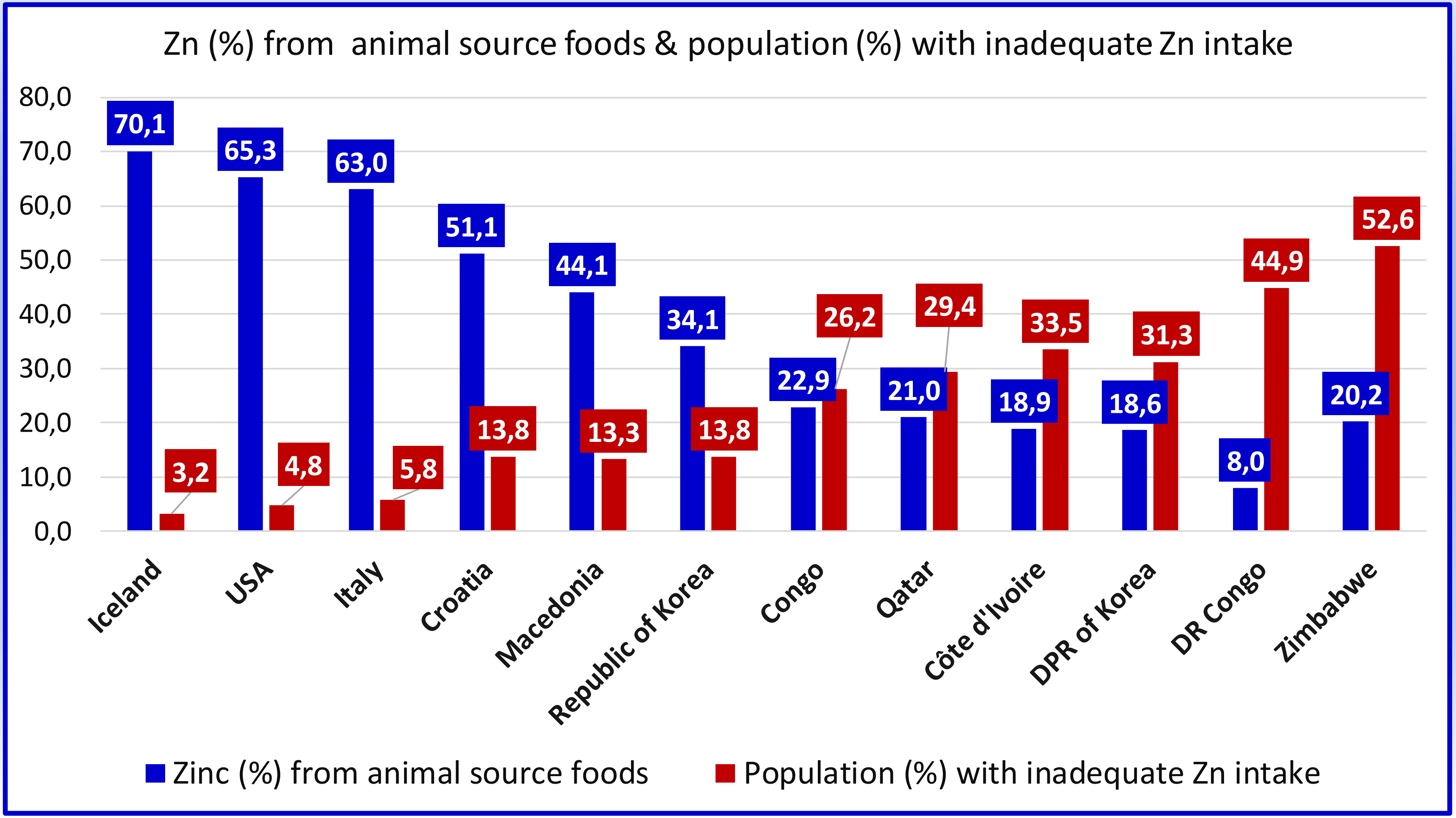
Zinc deficiency worldwide. *Wessells & Brown (2012.): Estimating the Global Prevalence of Zinc Deficiency. PLOS ONE.*

Croatia *(low to medium risk)*
1990 – 2005:
10,7-16,4 % populations with insufficient dietary Zn intake
Total Zn from animal source food:
46,3-56,4%

Italy *(low risk)*
1990 – 2005:
5,2 – 5,6 % populations with insufficient dietary Zn intake
Total Zn from animal source foods:
62,3-63,6%

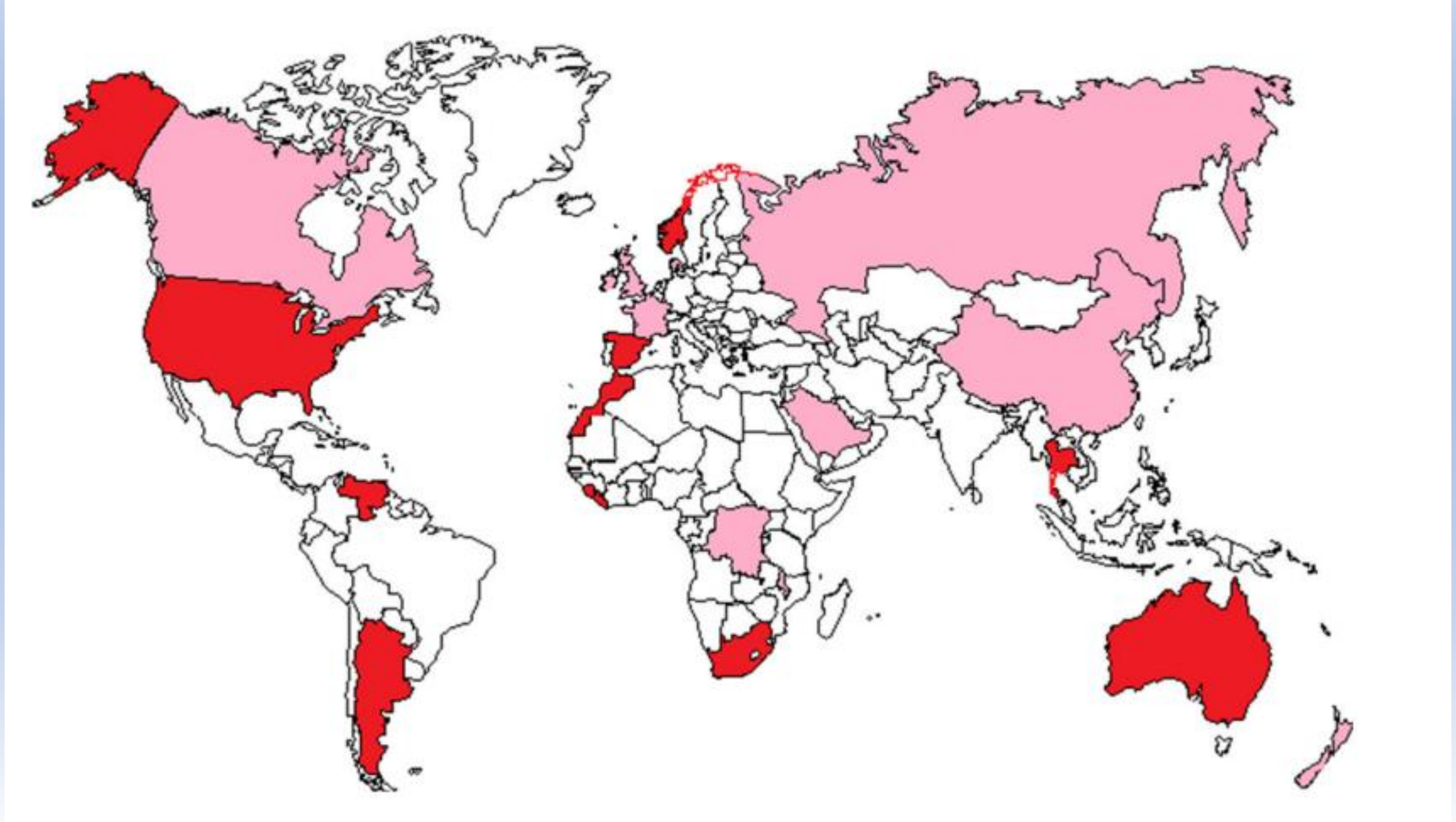
Wessells & Brown (2012.): Estimating the Global Prevalence of Zinc Deficiency. PLOS ONE.

Zn from animal source foods & population with inadequate Zn intake



Zinc deficiency worldwide. *Wessells & Brown (2012.): Estimating the Global Prevalence of Zinc Deficiency. PLOS ONE.*

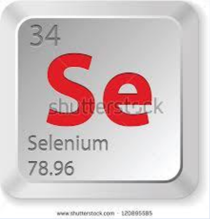
Se deficiency in soil



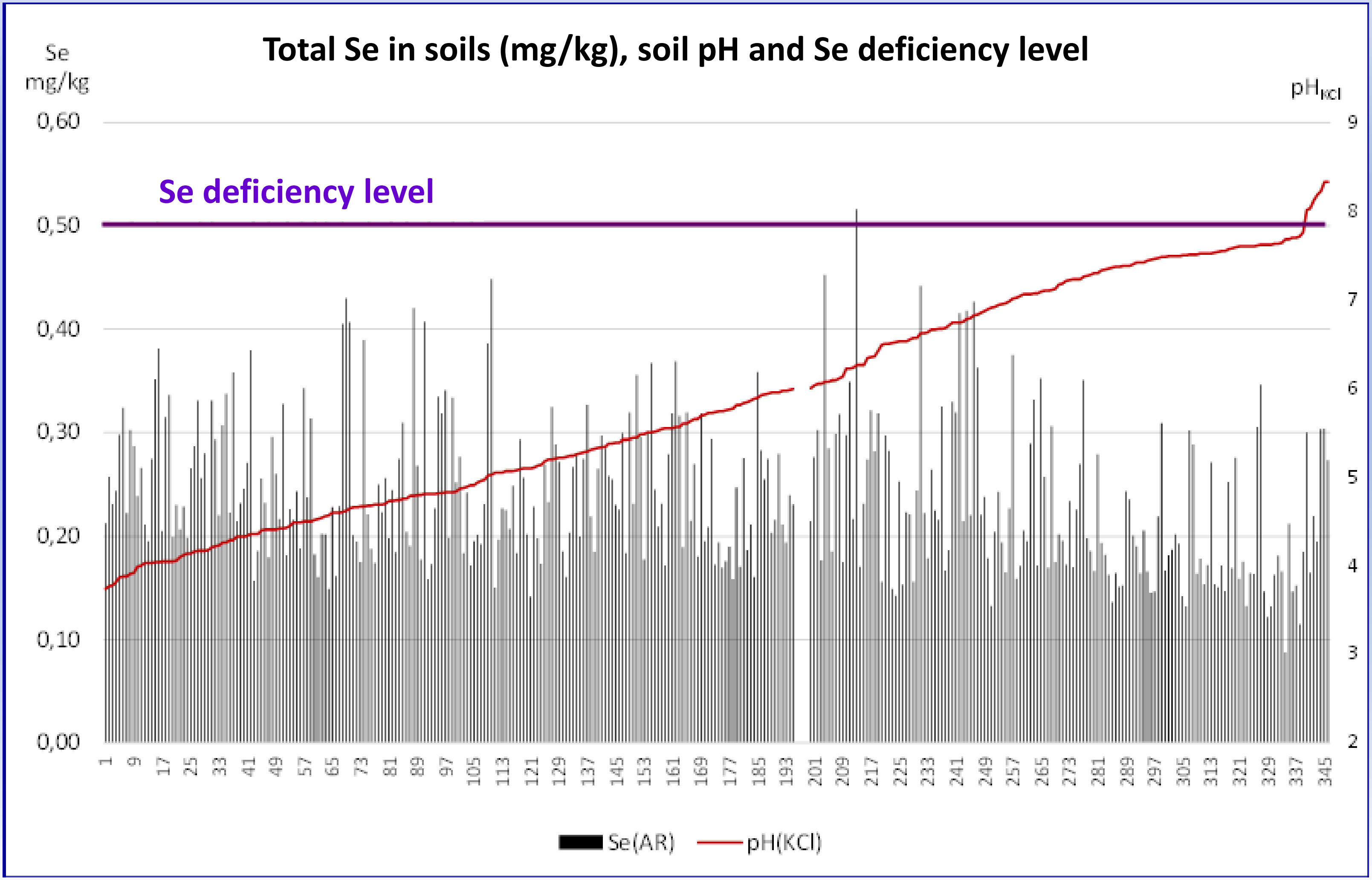
Global differences in Se concentrations in soils

Mombo i sur. (2015): Bioaccessibility of selenium after human ingestion in relation to its chemical species and compartmentalization in maize. Environ Geochem Health

*World regions **naturally enriched** in selenium (topsoil Se content exceeds 1.0 mg kg^{-1}) appear in **red (filled square)**, whereas **pink areas** correspond to regions with naturally **low Se** concentration (filled square) and white areas correspond to regions with **unknown concentration (opened square)***



Total Se concentrations in eastern Croatia soils



Concentration of total Se in the soils of eastern Croatia

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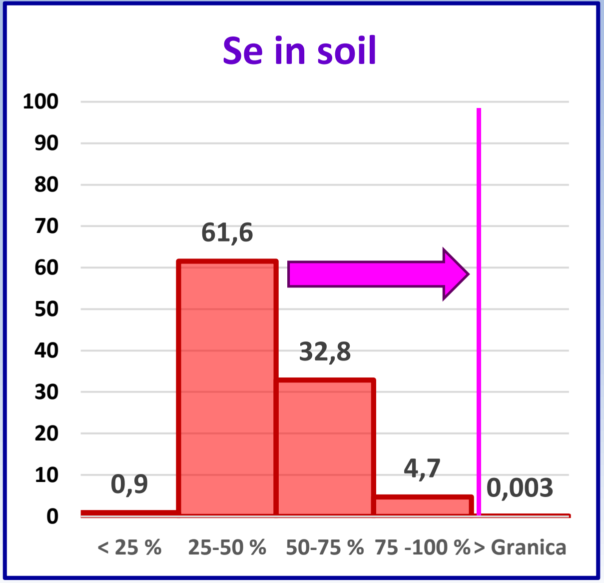
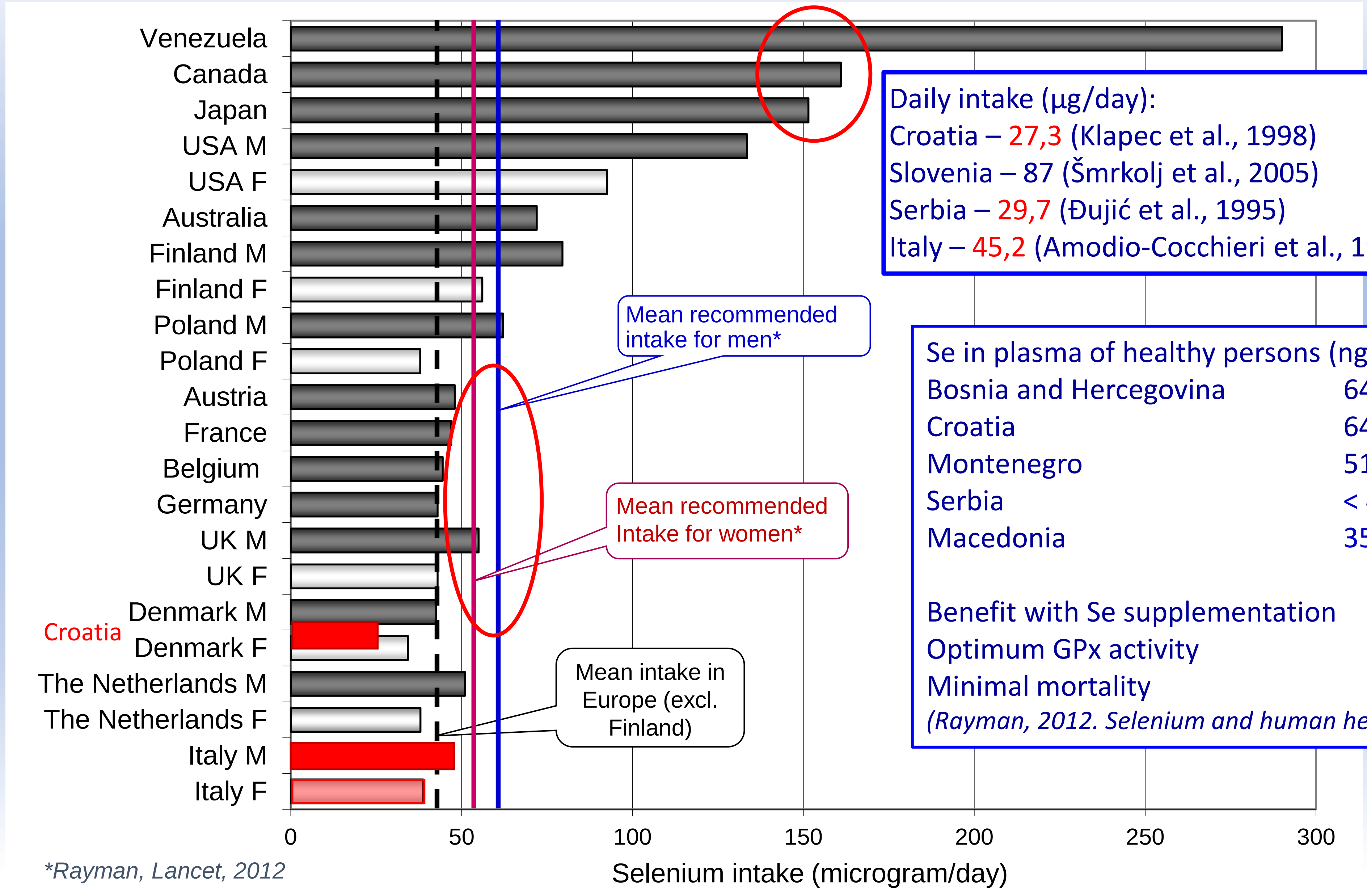


Global variation in selenium intake



Evaluation of the Se content of the traditional Italian diet
Amodio-Cocchieri R., Arnese A., Roncioni A. & Silvestri G. (1995) *International Journal of Food Sciences and Nutrition*

Daily intake (µg/day):
Croatia – 27,3 (Klapec et al., 1998)
Slovenia – 87 (Šmrkolj et al., 2005)
Serbia – 29,7 (Đujić et al., 1995)
Italy – 45,2 (Amodio-Cocchieri et al., 1995)

Se in plasma of healthy persons (ng Se ml^{-1}):

Bosnia and Hercegovina	64 (1992)
Croatia	64 (1992)*
Montenegro	51 (1992)
Serbia	< 45 (1992)
Macedonia	35 (1992)
Benefit with Se supplementation	< 122
Optimum GPx activity	122-130
Minimal mortality	130-150

(Rayman, 2012. Selenium and human health. Lancet 379: 1256–1268.)

Global variation in Se intake Fairweather-Tait i sur. (2011.) Lancet.

Biofortification as prevention of malnutrition

- Genetic biofortification – the best strategy as a long-term sustainable solution to prevent micronutrient malnutrition.

- It includes the selection of varieties as a first step and the breeding of new genotypes with a higher concentration of micronutrients.

- So far, genetic biofortification is more effective in preventing zinc (Zn) malnutrition than selenium (Se).

Agronomic (bio)fortification

- Agronomic biofortification (agrofortification) is an effective short-term solution.

- It includes the use of micronutrients (microfertilizers) in the cultivation of crops in accordance with the properties of the soil with the aim of increasing the concentration of microelements in the edible part of the plant.

- So far, this strategy is very effective for selenium (Se) and moderately effective for zinc (Zn), depending on the plant species.

Other objectives of biofortification

- Increasing the bioavailability of microelements in food of plant origin.

- It is necessary, along with increasing the concentration of microelements, to reduce or maintain at the same level the concentration of antinutrients (eg. phytate).

- It is desirable, for example, to maintain the phytate/Zn ratio at values < 15.

- Reduce or maintain low concentrations of harmful elements in food of plant origin (eg. Cd)

I. Wheat biofortification

- Use the diversity of wheat genotypes.

- Use micronutrients in accordance with the soil properties with the aim of increasing the microelements density in the grain.

- So far, this strategy is very effective for selenium (Se) and moderately effective for zinc (Zn).

- The aim of biofortification is generally:
  - increasing Zn density in wheat grain to reach a concentration > 40 mg/kg
  - increasing Se concentration to reach 300 µg/kg.

I.1. Determined difference of genotypes in the accumulation of Zn, Fe and Cd

- Differences of 51 wheat genotypes in the accumulation of Zn and Fe on soil with and without contamination with Cd
- A group with 4 genotypes (varieties recognized in 1963, ‘84, ‘88 and ’98: Bezostaja 1, Slavonija, Ana, Golubica) with low Cd concentration and above-average concentrations of Zn and Fe

Rebekić, A. & Lončarić, Z. (2016): ***Genotypic difference in cadmium effect on agronomic traits and grain zinc and iron concentration in winter wheat****. Emirates Journal of Food and Agriculture, 28 (11), 772-778.*

Emirates Journal of Food and Agriculture. 2016. 28(11): 772-778
doi: 10.9755/ejfa.2016-05-475
http://www.ejfa.me/

REGULAR ARTICLE

Genotypic difference in cadmium effect on agronomic traits and grain zinc and iron concentration in winter wheat

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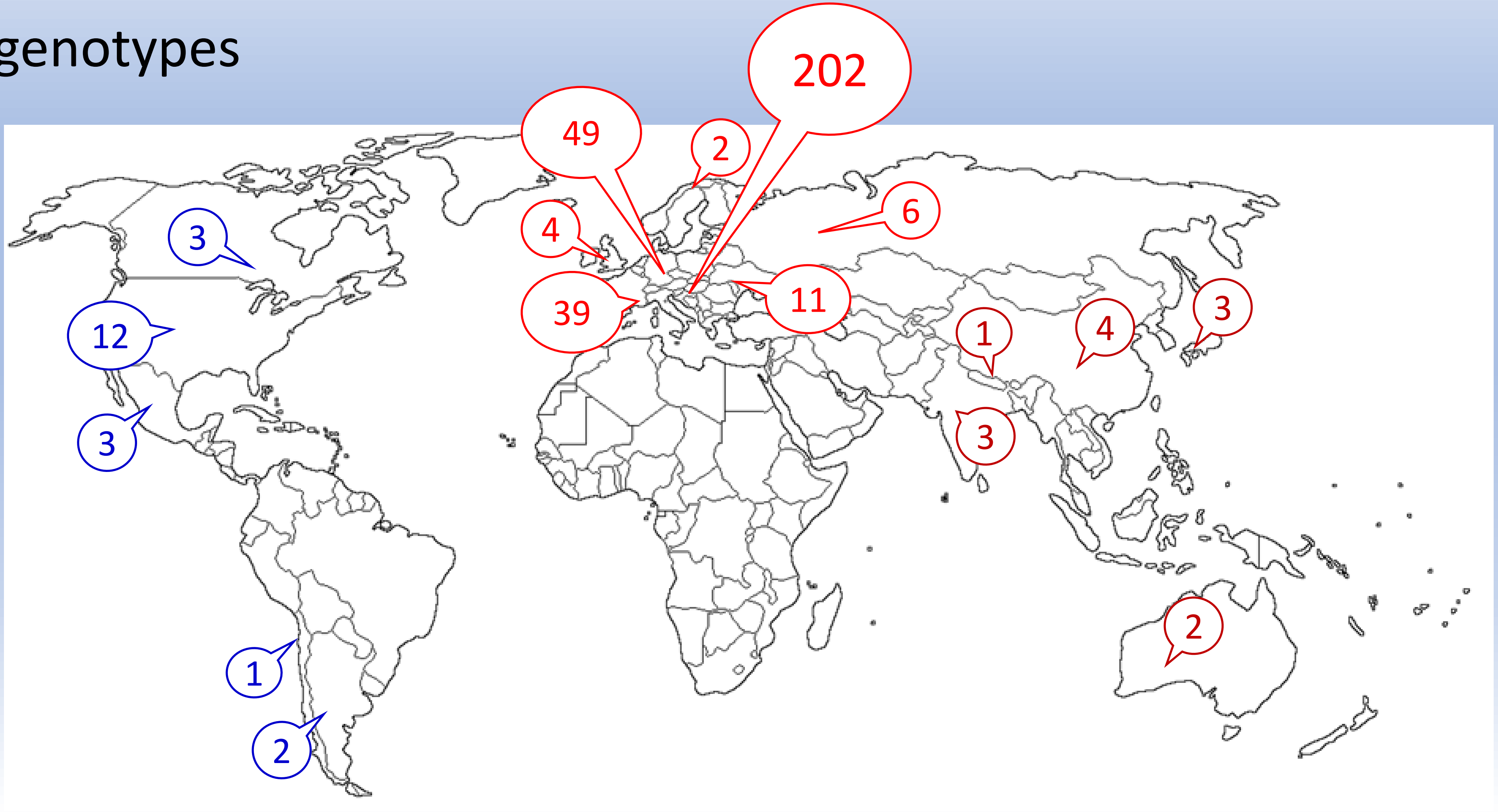
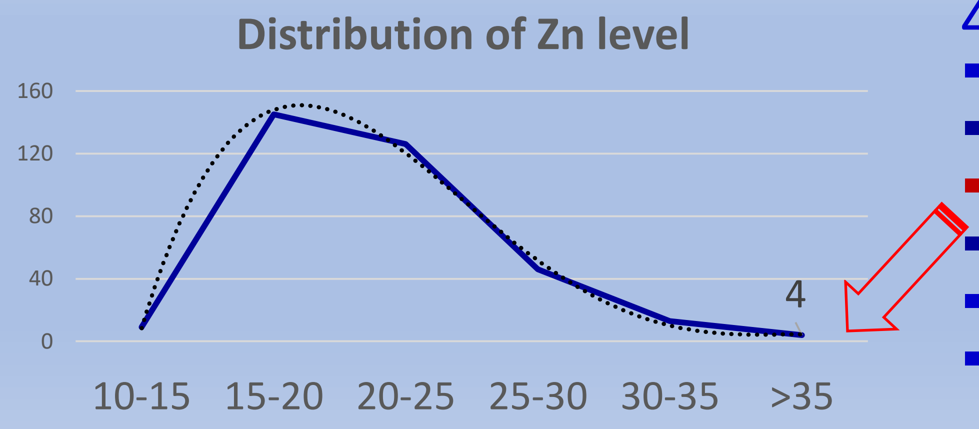
I.2. Determined difference of wheat genotypes (Zn, Fe, phytate)

- 343 wheat genotypes



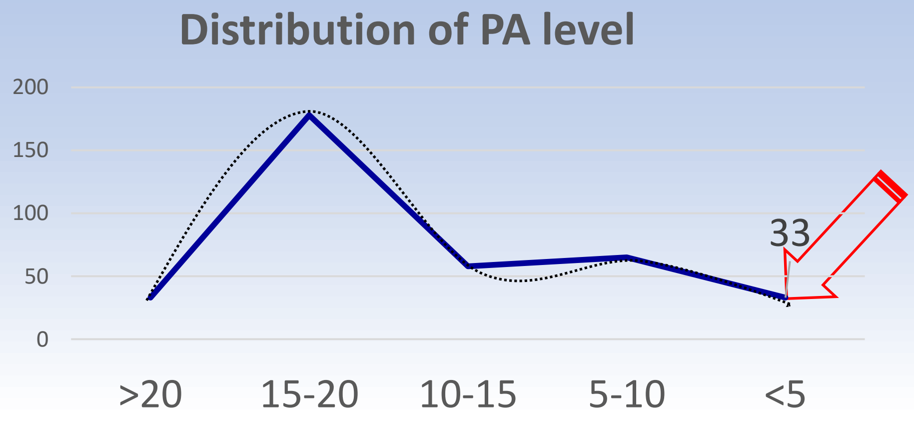
I.2. Determined difference of wheat genotypes (Zn, Fe, phytate)

- differences between wheat genotypes in Zn and phytate concentrations



Zn

- AVG 21,35 mg/kg
- MIN 13,30
- MAX 38,93
- no genotypes > 40 mg/kg
- TOP 10: 1931 – 2009
- TOP 3: 1962 – 2009

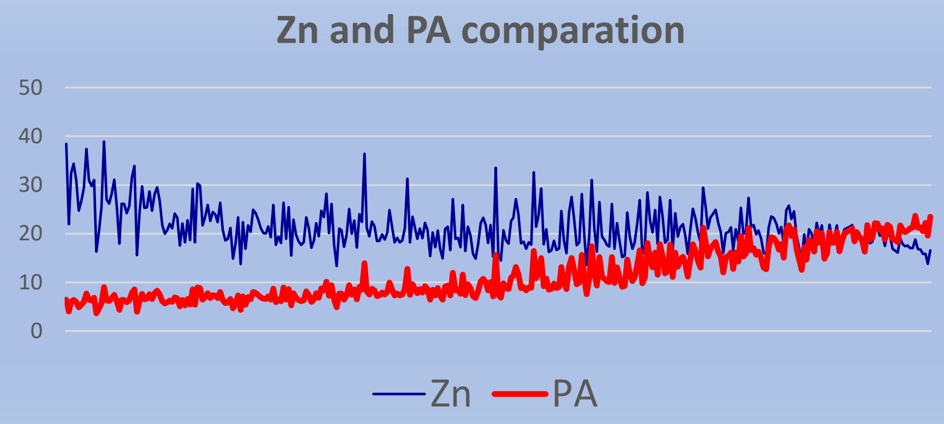


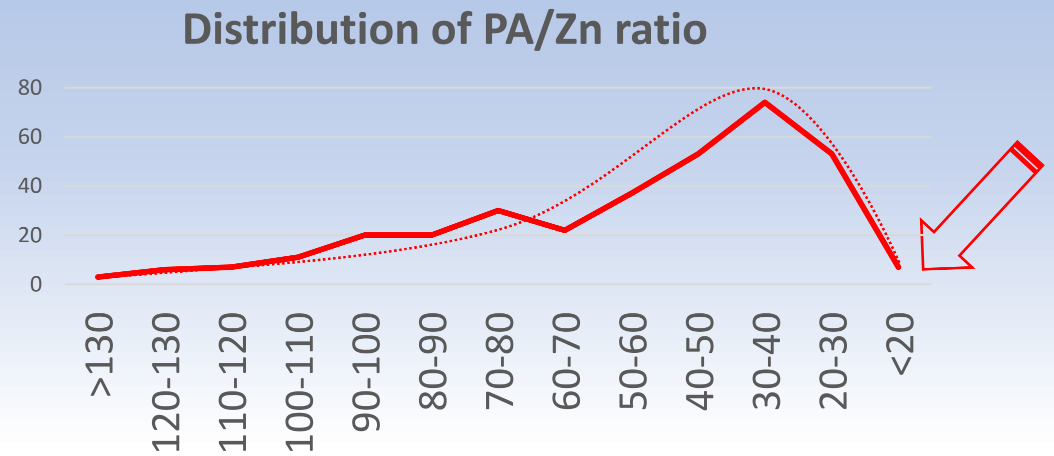
PA

- AVG 11,37 g/kg
- MIN 3,62
- MAX 23,68
- TOP 10: 1960-2006
- TOP 3: 1960-2006

I.2. Determined difference of wheat genotypes (Zn, Fe, phytate)

- the difference of wheat genotypes in the [phytate]/[Zn] ratio was determined



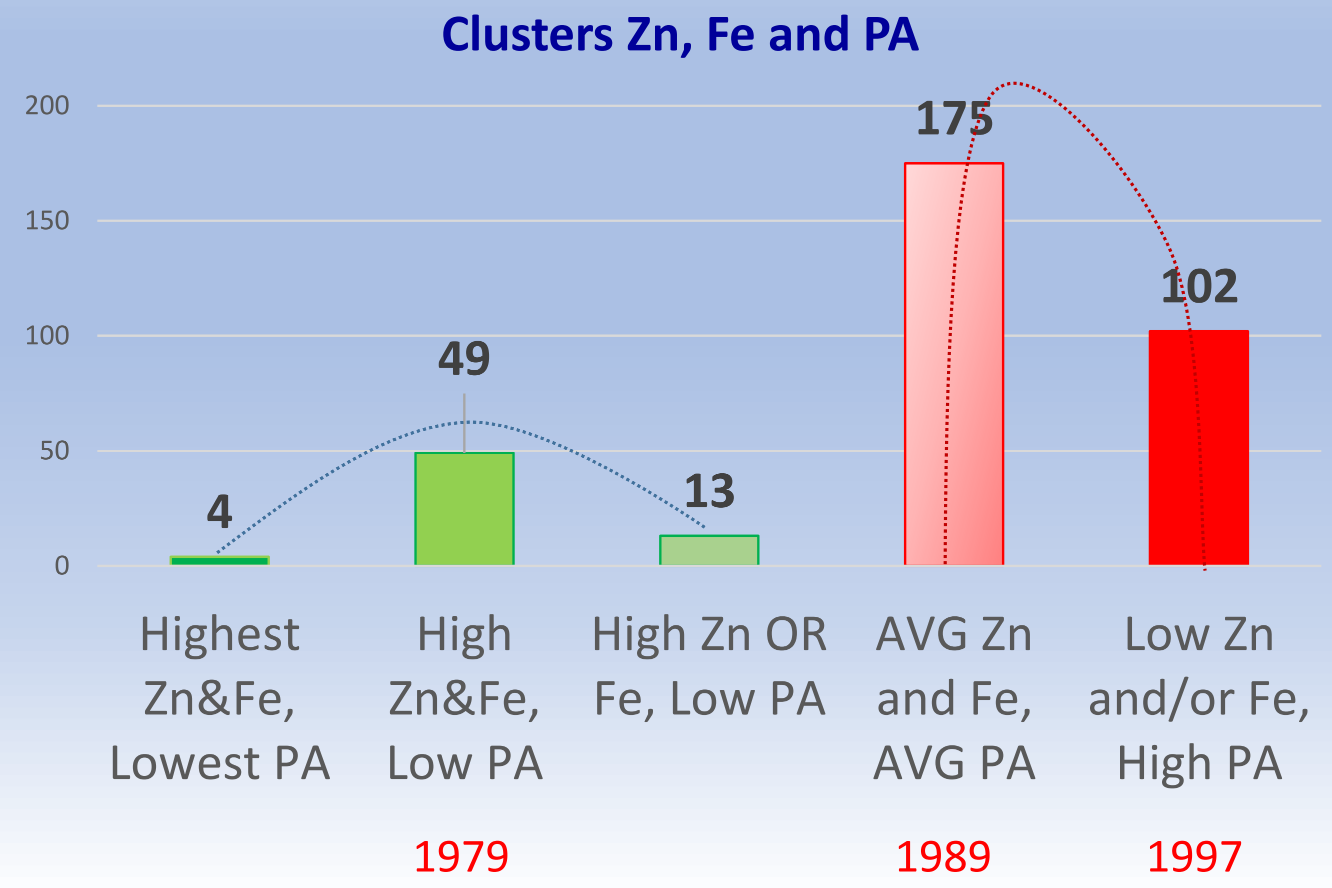


PA/Zn

- AVG 55
- MIN 16,5
- MAX 140
- no genotypes PA/Zn < 15
- PA/Zn 15-20: 7 genotypes
- TOP 3: 1960-1972
- TOP 10: 1960-1993

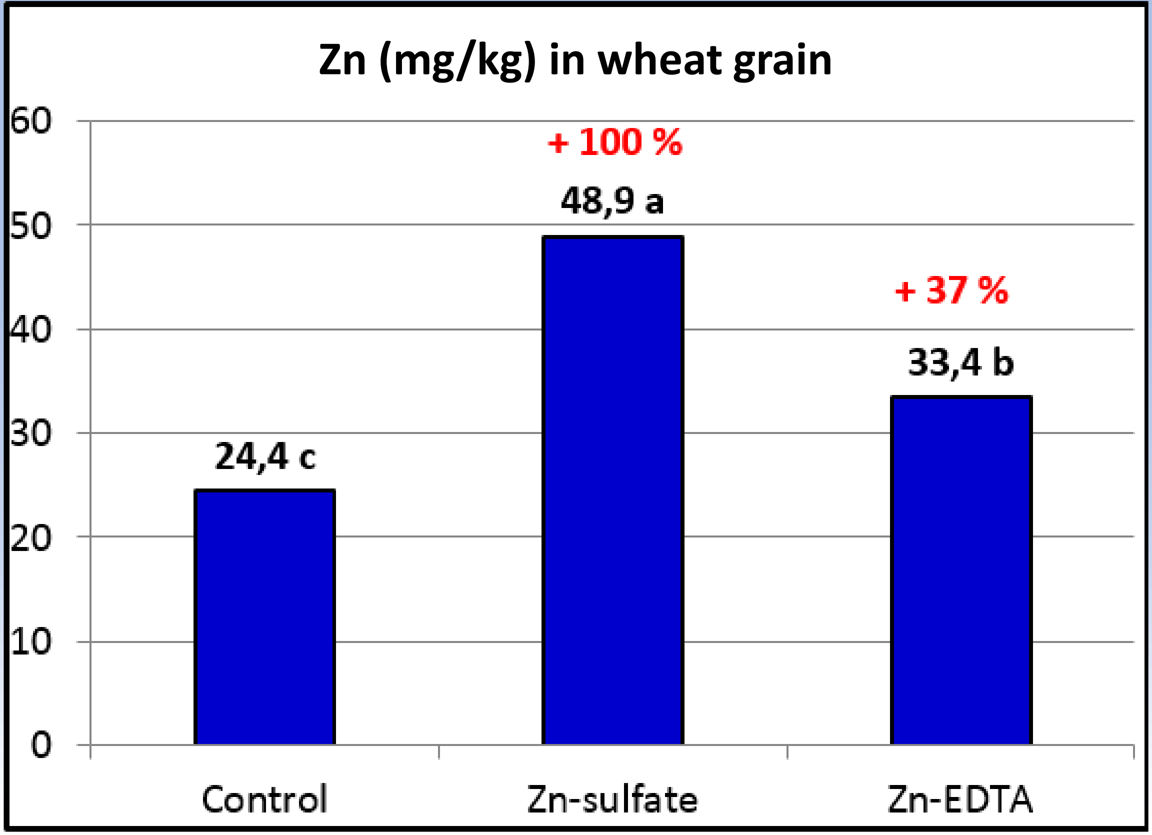
I.2. Determined difference of wheat genotypes (Zn, Fe, phytate)

- 5 different groups (clusters) of wheat genotypes were determined



I.3. Agronomic biofortification of wheat with Zn

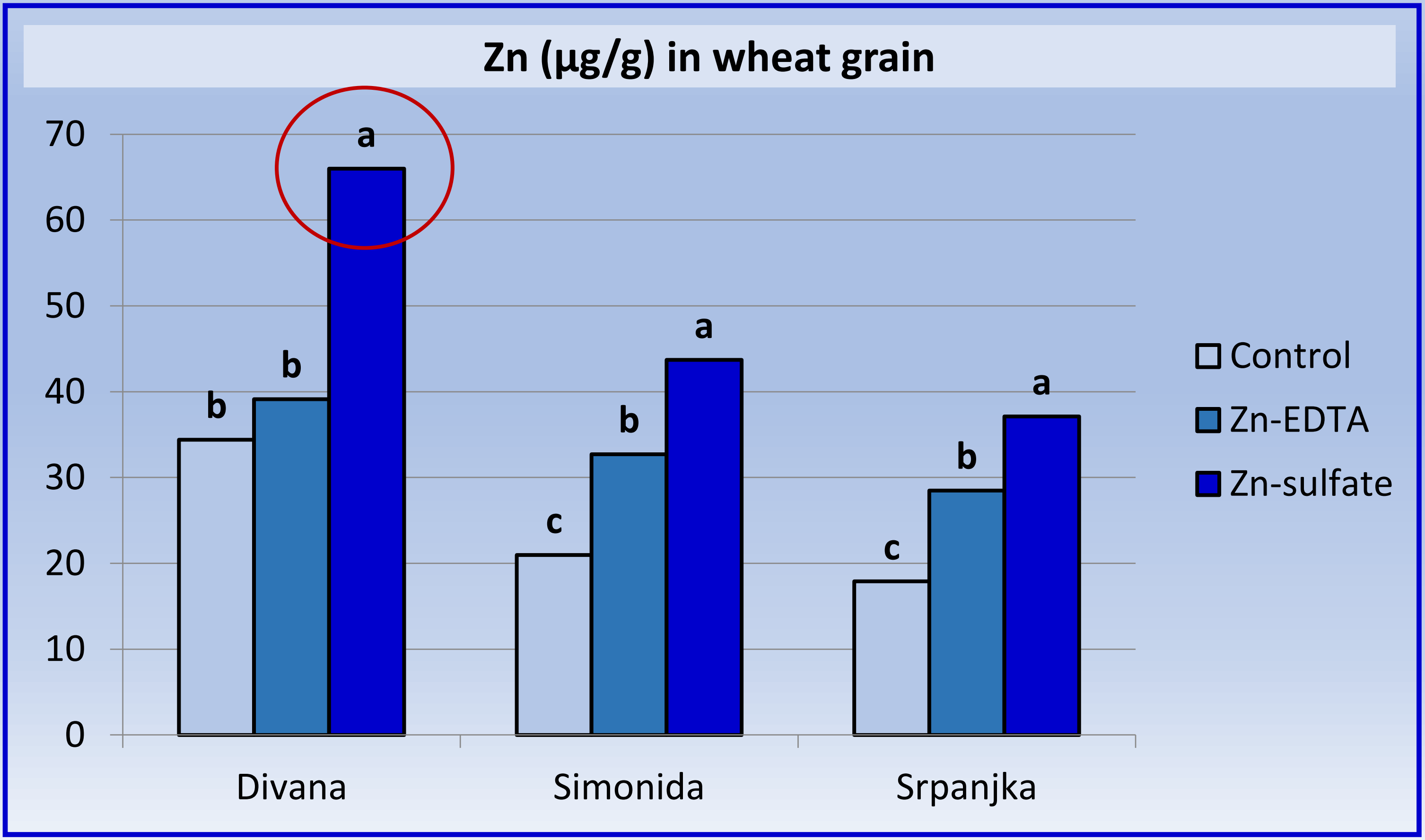
- foliar application of 1.5 kg Zn ha^{-1}
- Zn applied in 2 different forms (Zn-sulfate and Zn-EDTA) on 3 wheat varieties



- *A successful average increase of Zn concentration in wheat grain.*
- *More successful application of Zn in the form of sulfate than in the form of EDTA.*

I.3. Agronomic biofortification of wheat with Zn

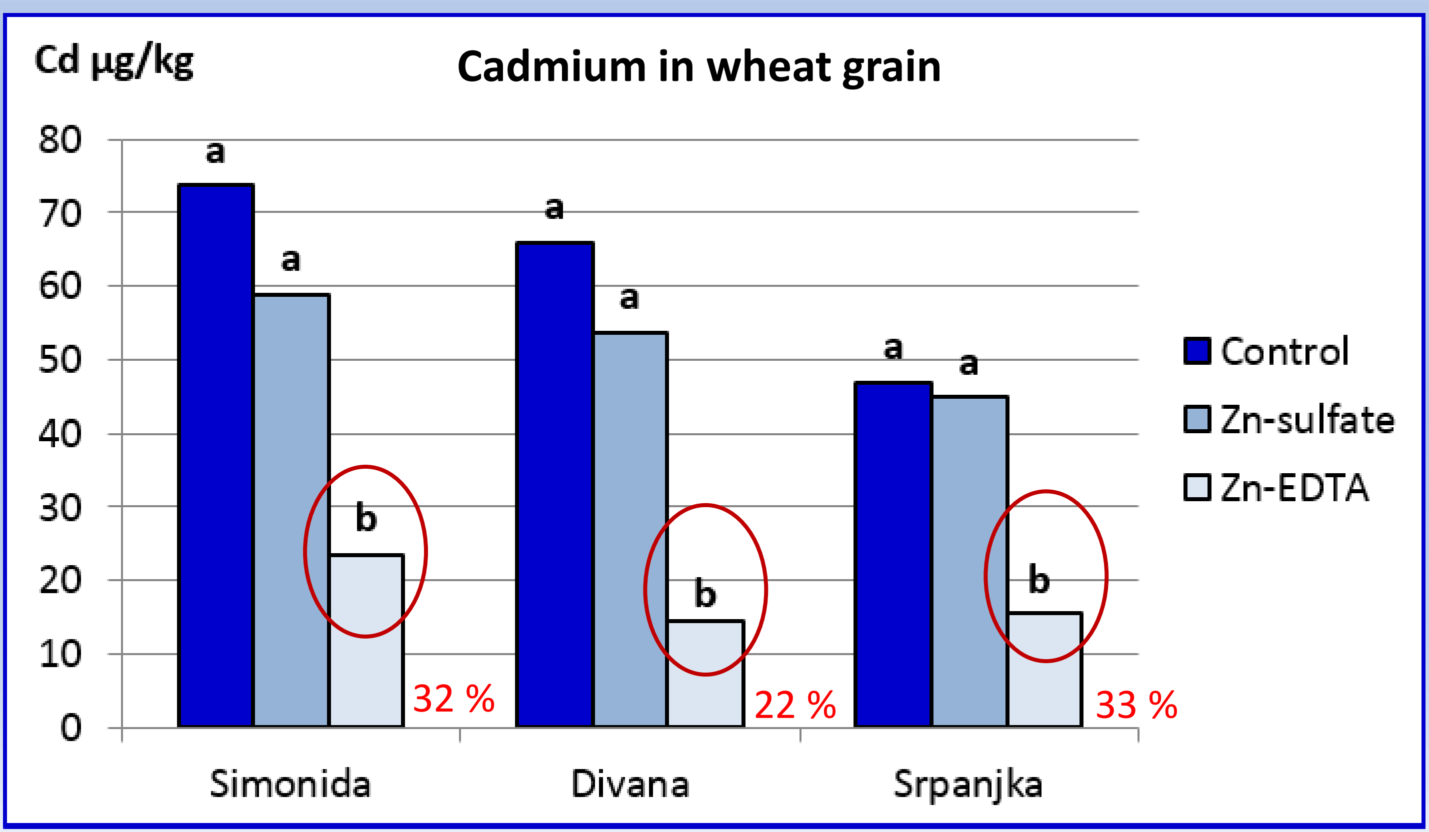
Effect of form of Zn and wheat variety on Zn in grain (µg/g)



- *The highest concentrations of Zn in the grain of the Divana variety (high-quality variety).*
- *The lowest concentration in the grain of the most productive variety (Srpanjka).*
- *Application of Zn in the form of sulfate is more effective on all varieties.*

I.3. Agronomic biofortification of wheat with Zn

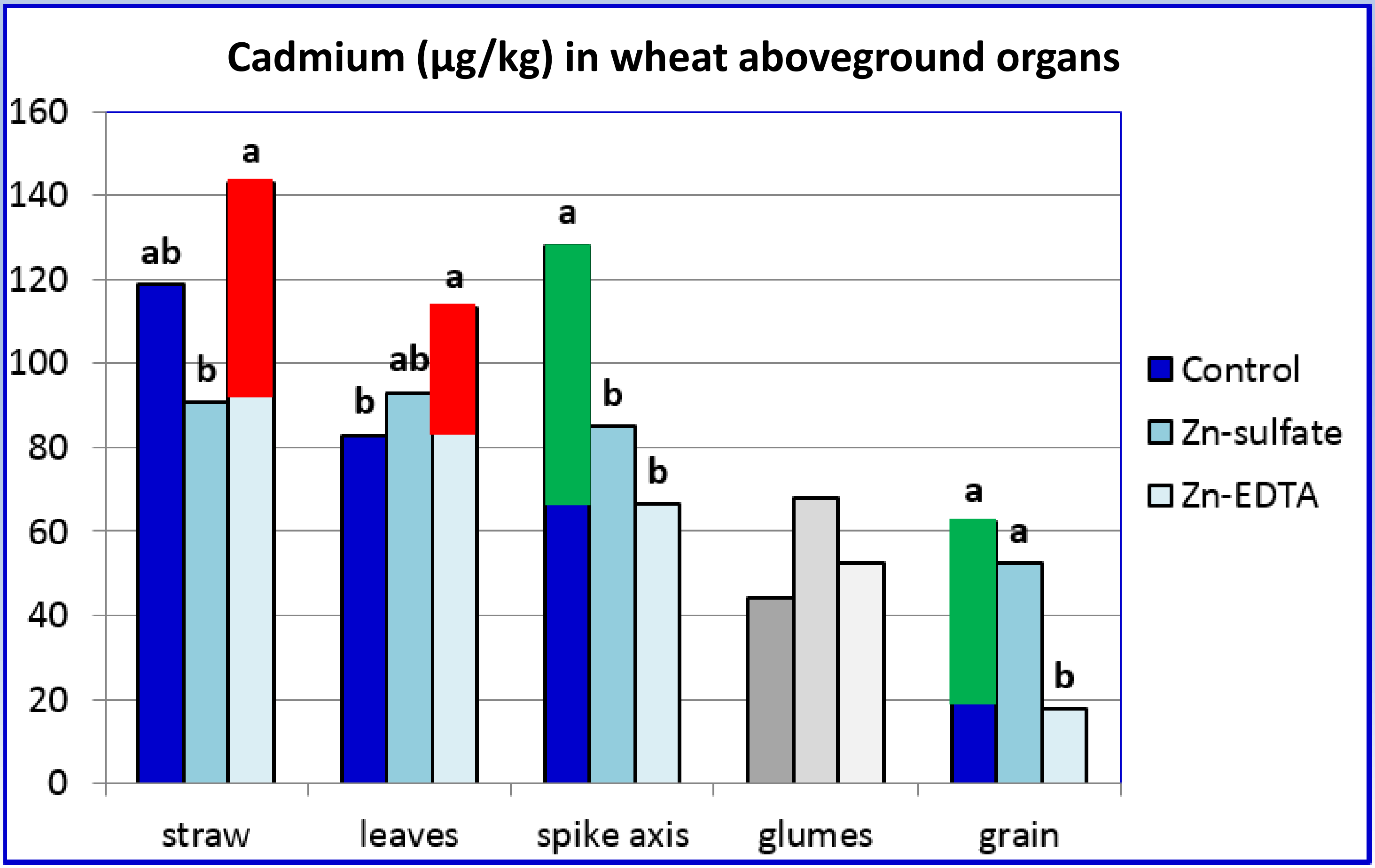
Effect of form of Zn and wheat variety on Cd in grain (μg/kg)



- *Cd concentrations in grain are very low (22-37% MAC)*
- *The highest concentrations of Cd in the grain without Zn application.*
- *The lowest concentrations of Cd in grain with the Zn applied as Zn-EDTA.*
- *The concentrations of Cd are at the level of 22-33% of the concentrations at the control treatment.*

I.3. Agronomic biofortification of wheat with Zn

Effect of Zn application on Cd in aboveground wheat organs

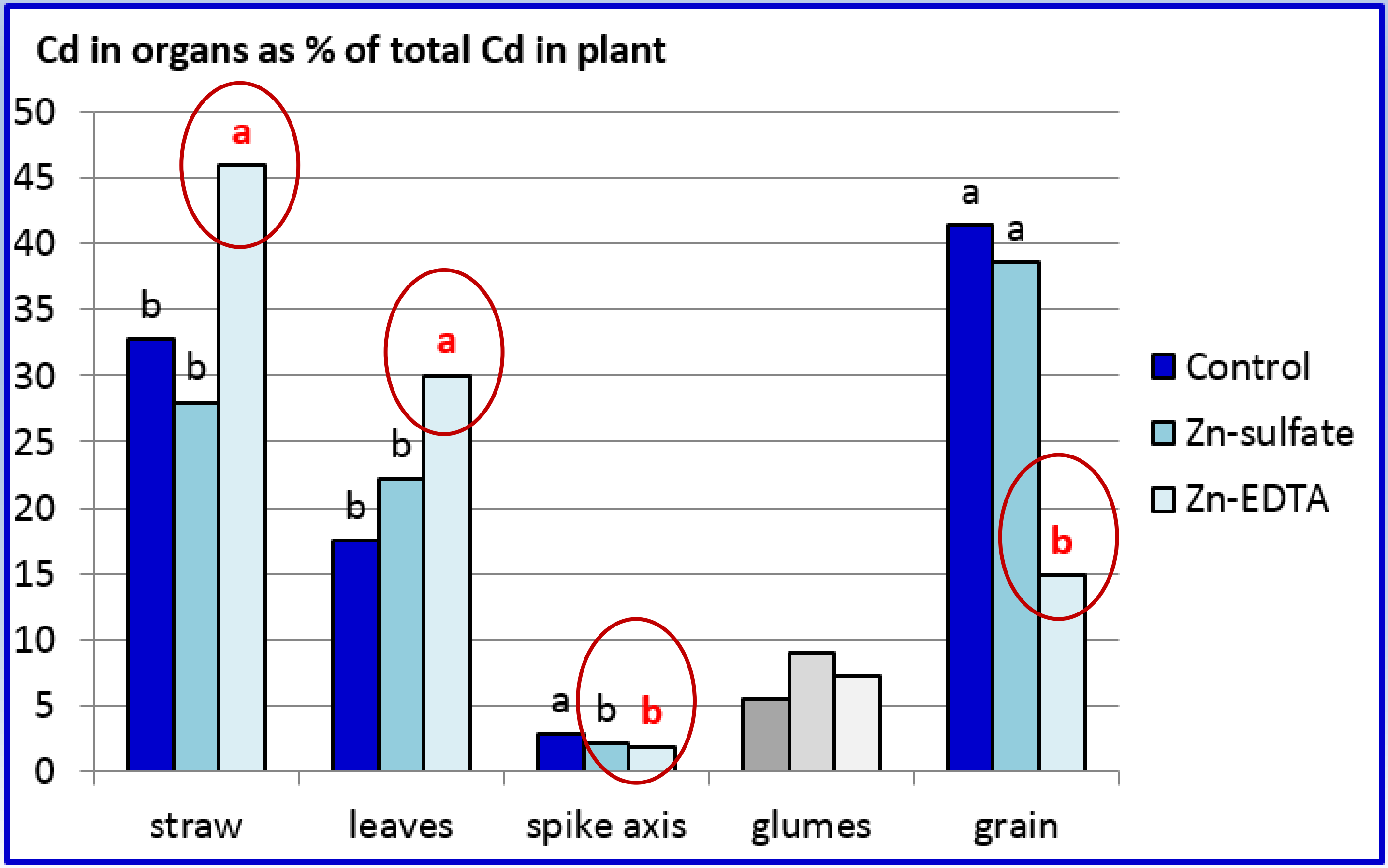


- *Significant decreasing of Cd concentration in spike axis and grain after Zn-EDTA application compared to control*

- *Significant increase in Cd concentration in straw and/or leaves after Zn-EDTA application compared to the control and Zn-sulfate application*

I.3. Agronomic biofortification of wheat with Zn

The influence of Zn on the distribution of Cd in above-ground organs

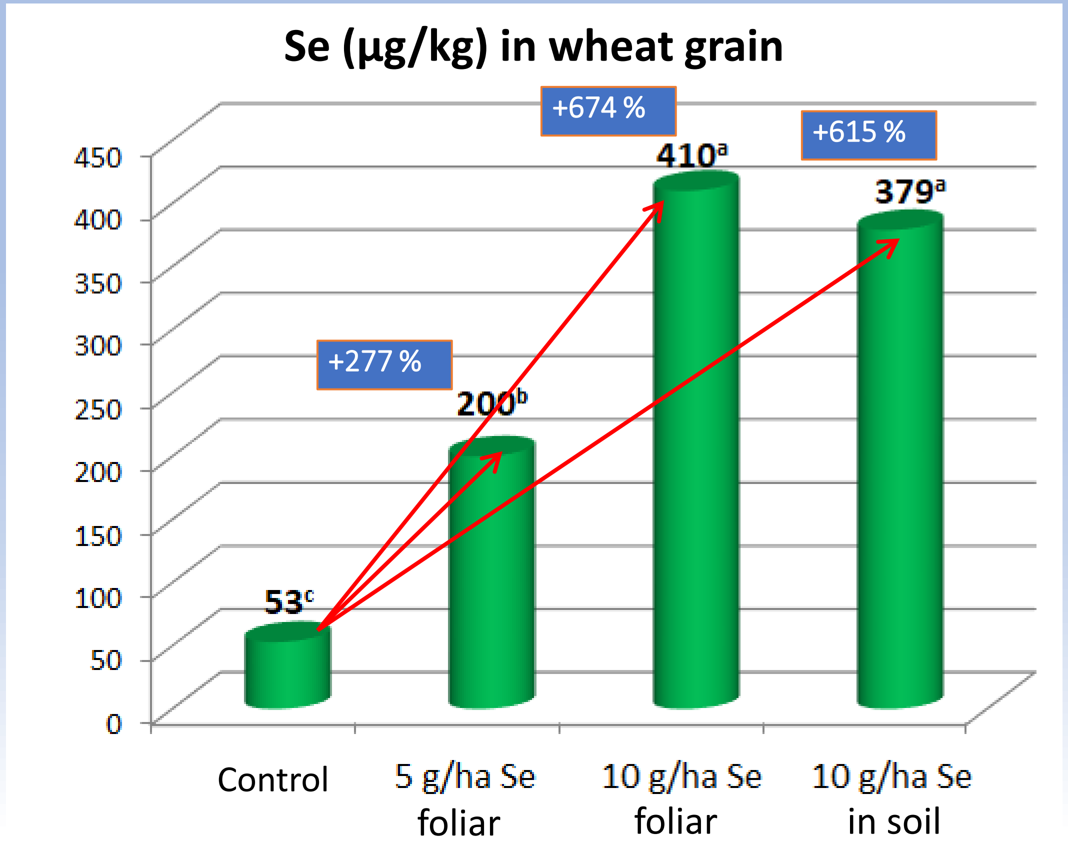


- *About 40% of the total amount of Cd was accumulated in wheat grain without Zn application and with Zn-sulfate application*

- *After the Zn-EDTA application, only 15% of the total amount of Cd was accumulated in the grain, and in straw and leaves a total of 75% of Cd*

I.4. Agronomic biofortification of wheat with Se

- Se application on the soil (10 g/ha) or foliar Se application (5 and 10 g/ha).
- It was applied in the form of selenate on 3 varieties of wheat



- *Successful increase of Se concentration in wheat grain (above 300 µg/kg).*
- *The foliar application of Se resulted in the accumulation of up to 40% of the applied Se in the grain, and the application of Se on the soil 19-39%.*
- *No significant difference between the genotypes*

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Taylor & Francis
Taylor & Francis Group
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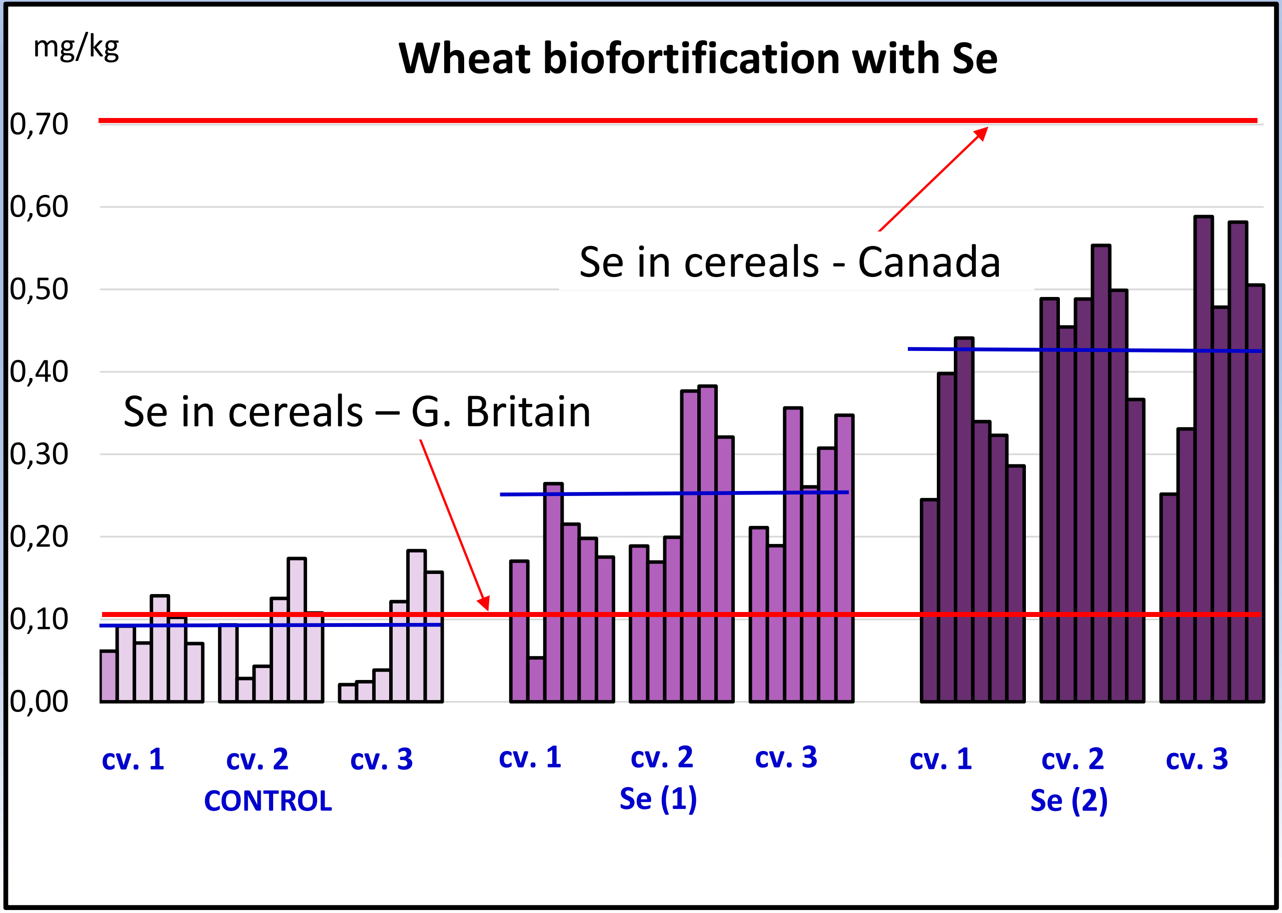
Biofortification of wheat cultivars with selenium

Maja S. Manojlović[a], Zdenko Lončarić[b], Ranko R. Cabilovski[a], Brigita Popović[b], Krunoslav Karalić[b], Vladimir Ivezić[b], Arsim Ademi[c] and Bal Ram Singh[c]

[a]Faculty of Agriculture, University of Novi Sad, Novi Sad, Serbia; [b]Faculty of Agobiotechnical Sciences, University J.J. Strossmayer in Osijek, Osijek, Croatia; [c]Faculty of Environmental Sciences and Natural Resource Management, Norwegian University of Life Sciences, Ås, Norway

I.4. Agronomic biofortification of wheat with Se

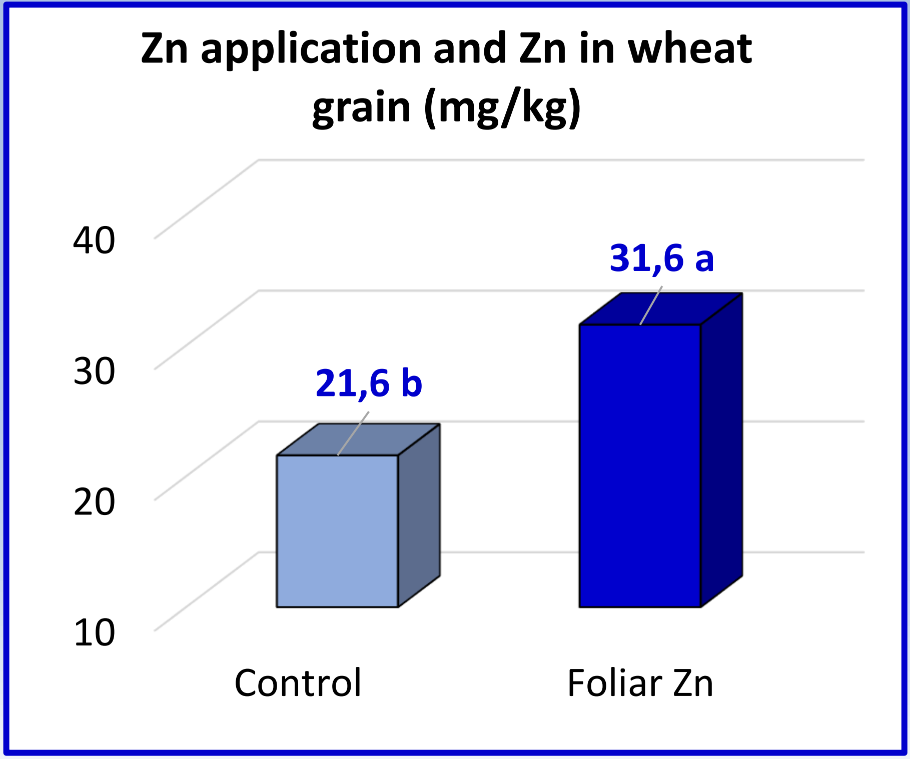
- Average results of several years of research on wheat biofortification with Se

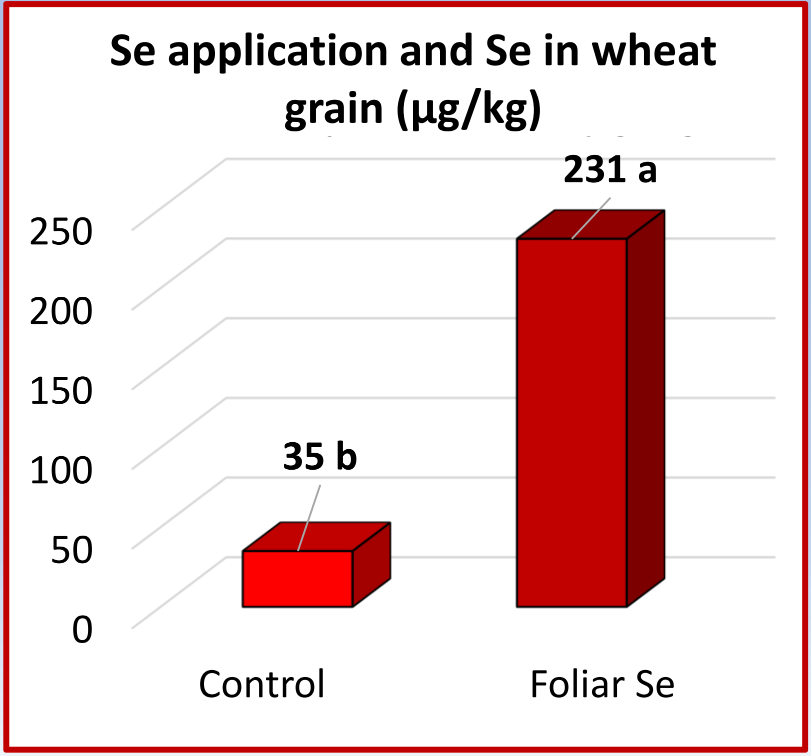


- *The application of 5 g/ha results in an Se average of 250 µg/kg in grain, but in varieties with a higher protein content, concentrations can be > 300 µg/kg.*
-
- *Application of 10 g/ha Se results in an average of 425 µg/kg, but only in certain years and varieties with low N, Se content was < 300 µg/kg*

I.5. Simultaneous biofortification (cobiofortification) with Zn and Se

- Impact of simultaneous foliar application of Zn (1.5 kg/ha) and Se (10 g/ha)
- 2 varieties of wheat with 4 levels of N fertilization (0, 110, 145, 180 kg/ha)

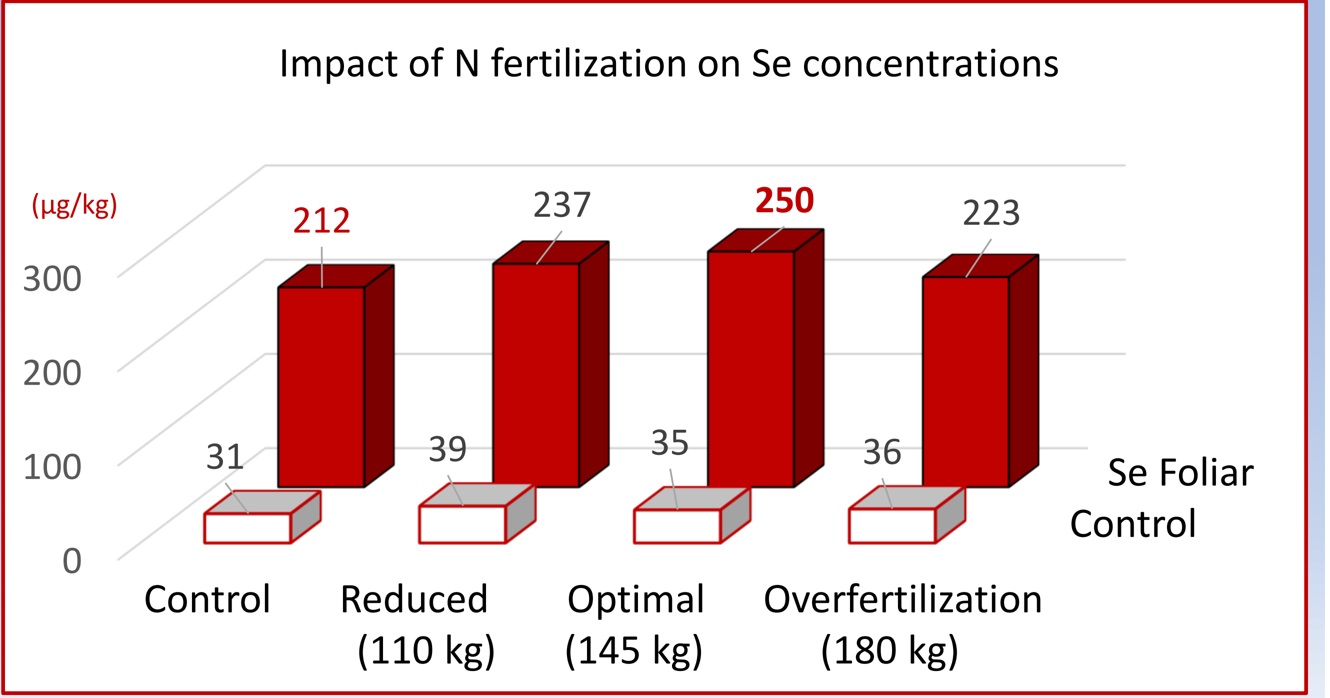




- *A simultaneous increase of both, Zn and Se concentration in wheat grain.*
- *Zn concentration 46% higher, but well below 40 mg/kg.*
- *Se concentration 6.6 times higher (560%), but still below 300 µg/kg*

I.5. Simultaneous biofortification (cobiofortification) with Zn and Se

- A low influence of fertilization on the success of wheat biofortification with Se, many times lower than the influence of Se application.



plants
MDPI
Article

Foliar Zinc-Selenium and Nitrogen Fertilization Affects Content of Zn, Fe, Se, P, and Cd in Wheat Grain

Zdenko Lončarić [1,2], Vladimir Ivezić [1], Darko Kerovec [3] and Andrijana Rebekić [4,*]

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2 Centre for Applied Life Sciences Healthy Food Chain Ltd., Vladimira Preloga 1, 31000 Osijek, Croatia
3 Central Laboratory for Agroecology and Environmental Protection, Faculty of Agrobiotechnical Sciences Osijek, Josip Juraj Strossmayer University of Osijek, 31000 Osijek, Croatia; dkerovec@fazos.hr
4 Department for Plant Production and Biotechnology, Faculty of Agrobiotechnical Sciences Osijek, Josip Juraj Strossmayer University of Osijek, 31000 Osijek, Croatia
* Correspondence: arebekic@fazos.hr

Abstract: The grain yield and concentrations of Fe, Zn, Se, Cd, and P in two winter wheat genotypes and in vitro bioaccessibility of Fe and Zn under the effect of different nitrogen fertilization and Zn-Se foliar application were evaluated. The total grain Fe, Zn, and Se concentrations, as well as Fe and Zn concentrations, after in vitro digestion were under the strongest effect of foliar Zn-Se application. On the other hand, Fe and Zn bioaccessibility (%) were under the most substantial effect of genotype. Regarding the need to increase concentrations of essential micronutrients in wheat grain, foliar Zn-Se application is a reliable and accepted agricultural practice, but to improve mineral bioaccessibility in human nutrition, foliar Zn-Se application should be combined with the most responsive genotypes. For this reason, further research on the genotype specificity of wheat regarding micronutrient bioaccessibility should be carried out.

check for updates

Citation: Lončarić, Z.; Ivezić, V.; Kerovec, D.; Rebekić, A. Foliar Zinc-Selenium and Nitrogen Fertilization Affects Content of Zn, Fe,

Keywords: biofortification; in vitro bioaccessibility; iron; selenium; zinc

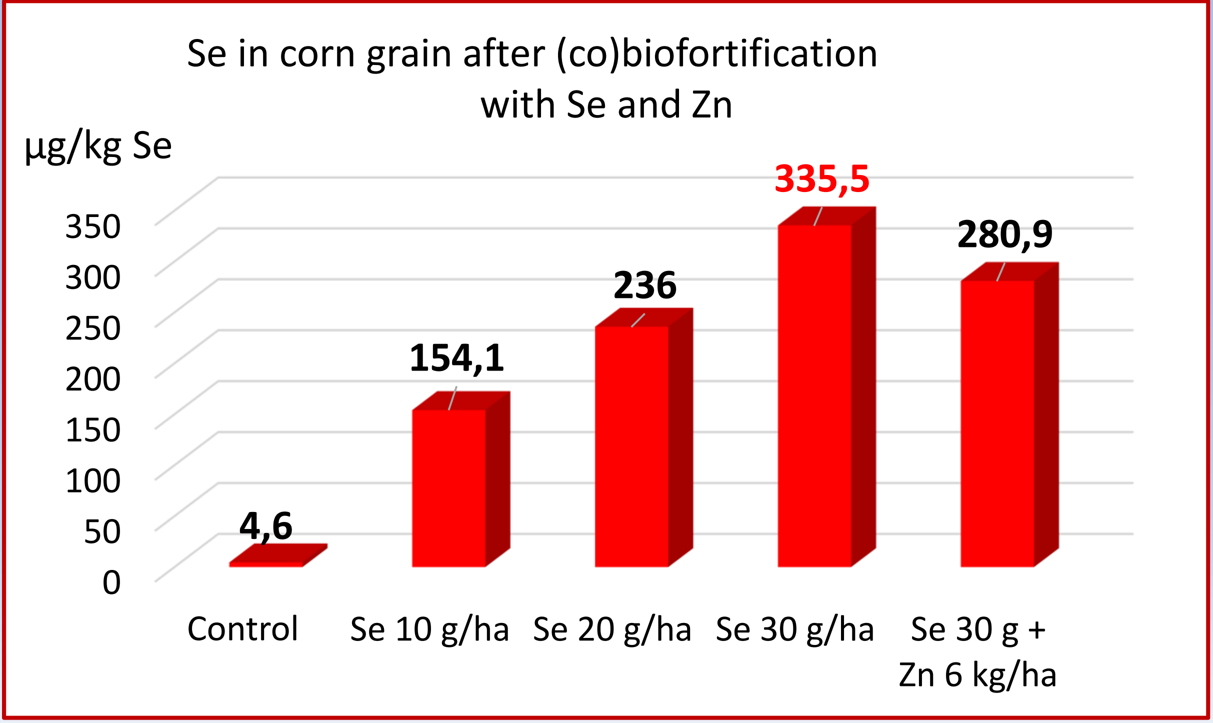
II. Corn biofortification

- It mostly involves the foliar use of micronutrients (Zn and Se) during corn cultivation in accordance with soil properties with the aim of increasing the concentration of Zn and/or Se in the corn grain.

- So far, it is very effective for selenium (Se) and with low efficiency in zinc (Zn) biofortification.

II.1. Agronomic biofortification of corn with Se

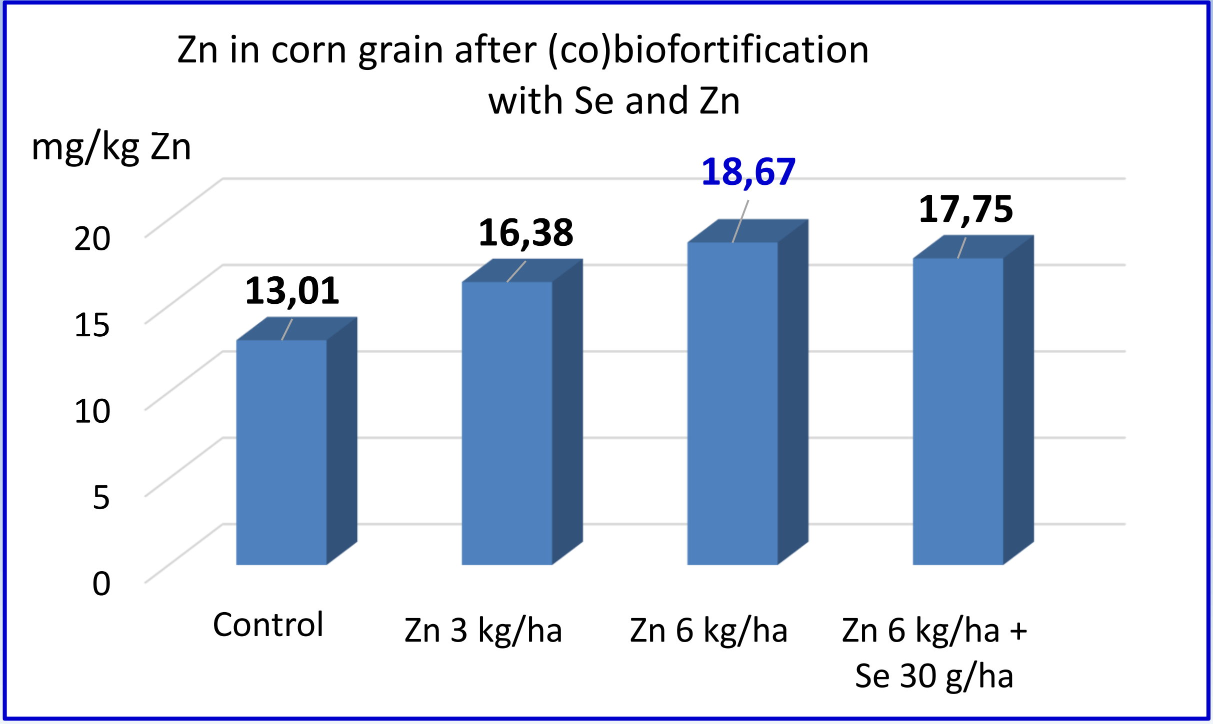
- Foliar single application of Se (10, 20 and 30 g/ha) and cobiofortification with Se (30 g/ha) and Zn (6 kg/ha).



- *A successful increase of Se concentration in corn grain.*
- *Increase in Se concentration 32-73 times*
- *Se concentration above 300 µg/kg only after addition of 30 g/ha Se.*
- *The simultaneous application of Se and Zn reduced the concentration of Se by 16%, but the impact is different on different soils*

II.2. Agronomic biofortification of corn with Zn

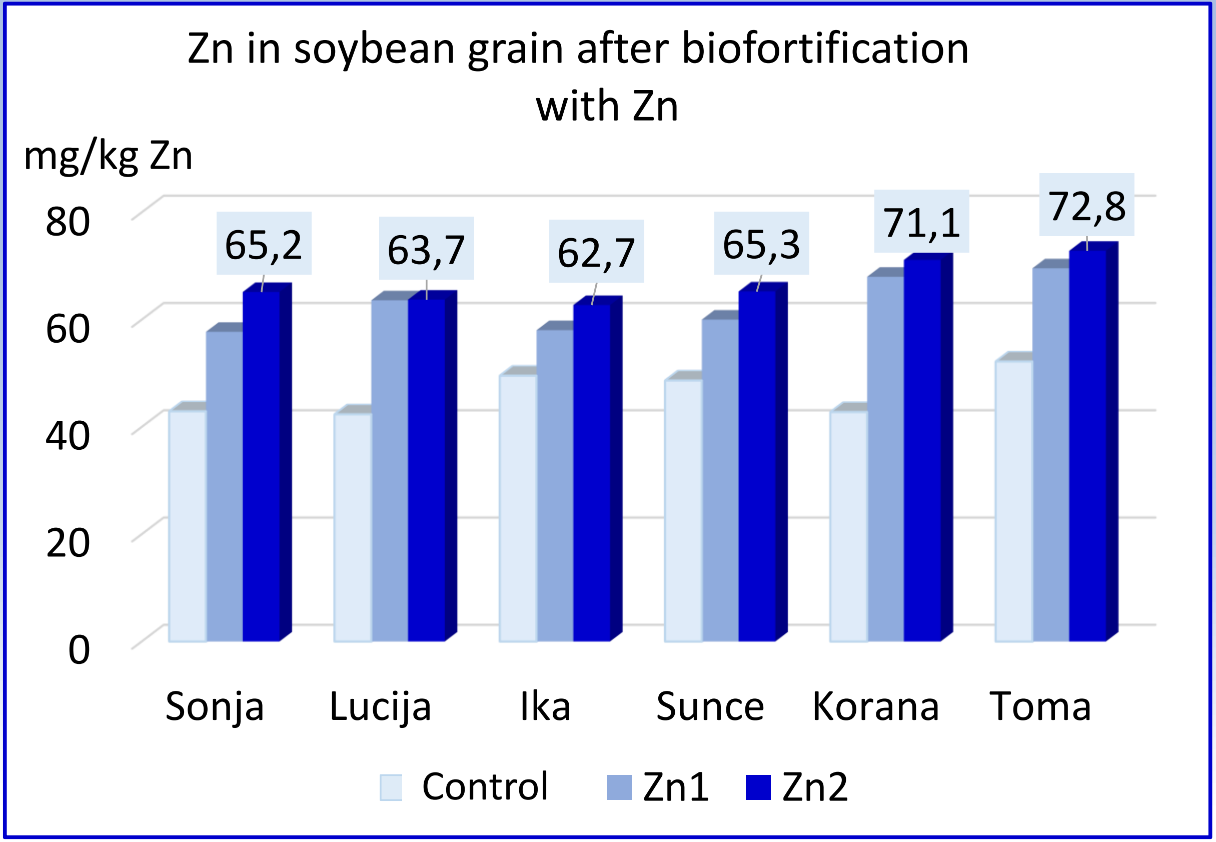
- Foliar single application of Zn (3 and 6 kg/ha) and cobiofortification with Zn (6 kg/ha) and Se (30 g/ha)



- *A slight increase in Zn concentration in corn grain.*
- *Increase in concentration by 5.66 mg/kg (45 %), but up to only 18.7 mg/kg with the addition of 6 kg/ha Zn.*
- *Simultaneous application of Se and Zn reduced the concentration of Zn by 0.92 mg/kg (comparing to only Zn application)*

III.1. Soybean biofortification with Zn

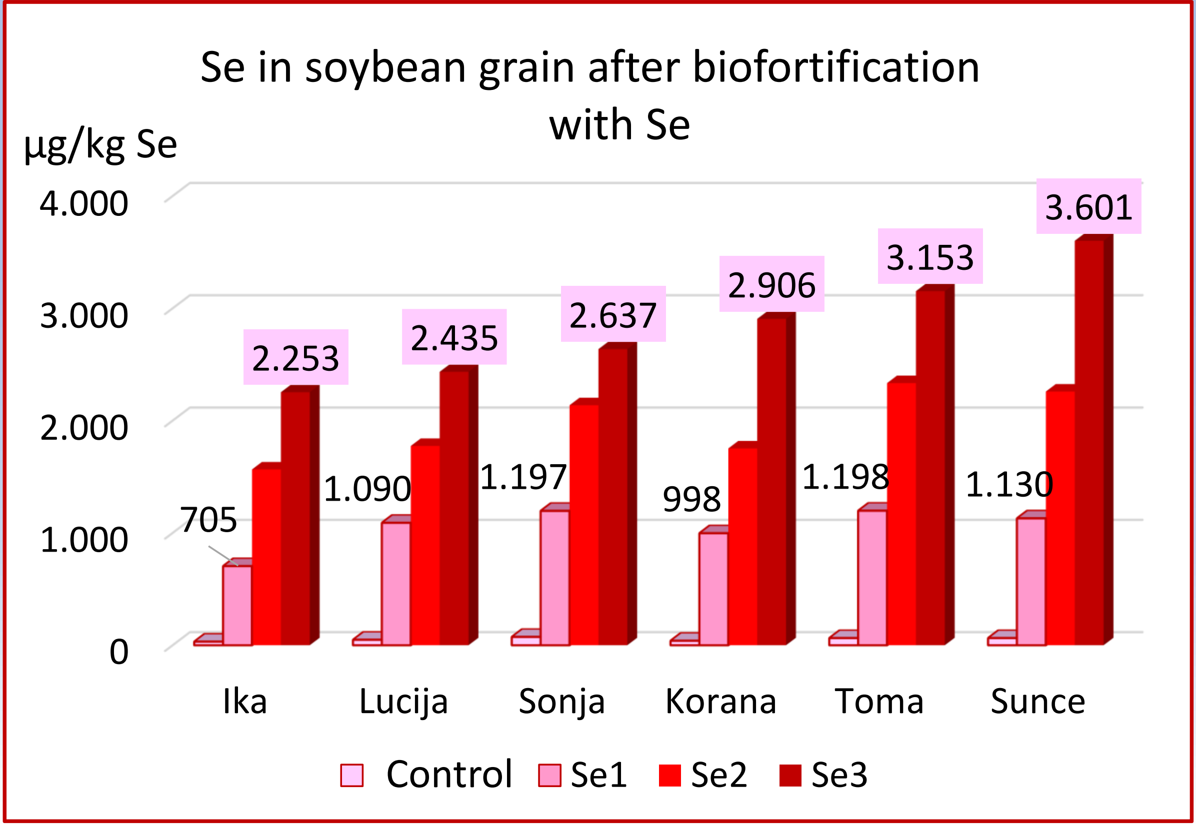
- Foliar application of Zn (3 and 6 kg/ha) on 6 soybean cultivars



- *A significant increase in the concentration of Zn in soybeans.*
- *All varieties had Zn concentrations > 40 mg/kg without Zn addition.*
- *Significant differences between soybean varieties: 3 varieties with about 40 mg/kg Zn, and the other 3 varieties with 15-23% higher concentration.*
- *Biofortification increased Zn by 16-66%*
- *Biofortified varieties in two groups: 4 with lower and 2 with higher Zn increasing*

III.2. Soybean biofortification with Se

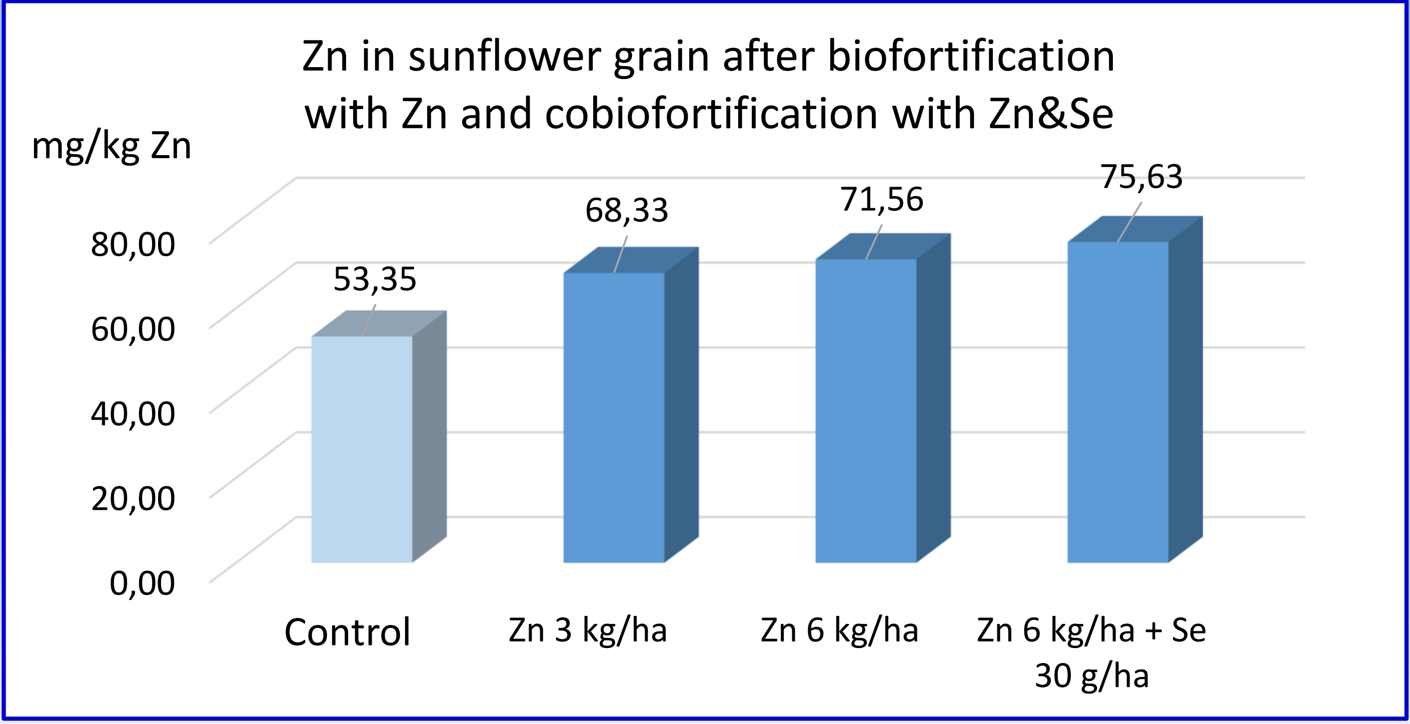
- Foliar application of Se (10, 20 or 30 g/ha) on 6 soybean cultivars



- *A significant increase in the concentration of Se in soybeans*
- *All cultivars with Se concentrations > 300 µg/kg (> 700) after the addition of 10 g Se/ha.*
- *For the target of 300 µg/kg, 5 g/ha Se is sufficient*
- *Significant differences between soybean cultivars, divided into 3 groups by biofortification: the 2nd group with 18% more Se than the 1st, and the 3rd with an additional 22% more Se than 2nd group.*
- *Great potential for forage enrichment*

IV.1. Sunflower agronomic biofortification with Zn

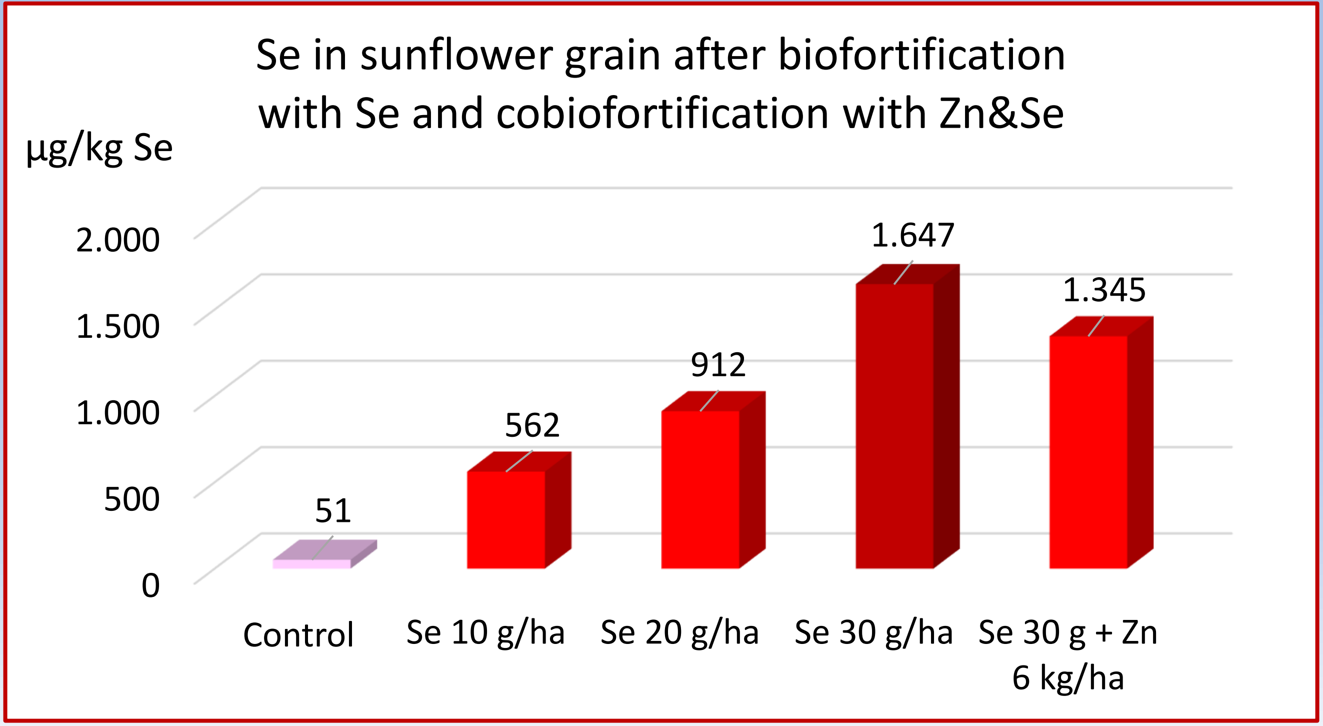
- Foliar application of Zn (3 and 6 kg/ha) and cobiofortification with Zn (6 kg/ha) and Se (30 g/ha)



- *Successful increase of Zn concentration in sunflower grain.*
- *Increase in concentration 28 – 42 %.*
- *The simultaneous application of Zn and Se did not reduce the Zn concentration*
- *Great potential for the production of enriched oil and enriched feed mixtures*

IV.2. Sunflower agronomic biofortification with Se

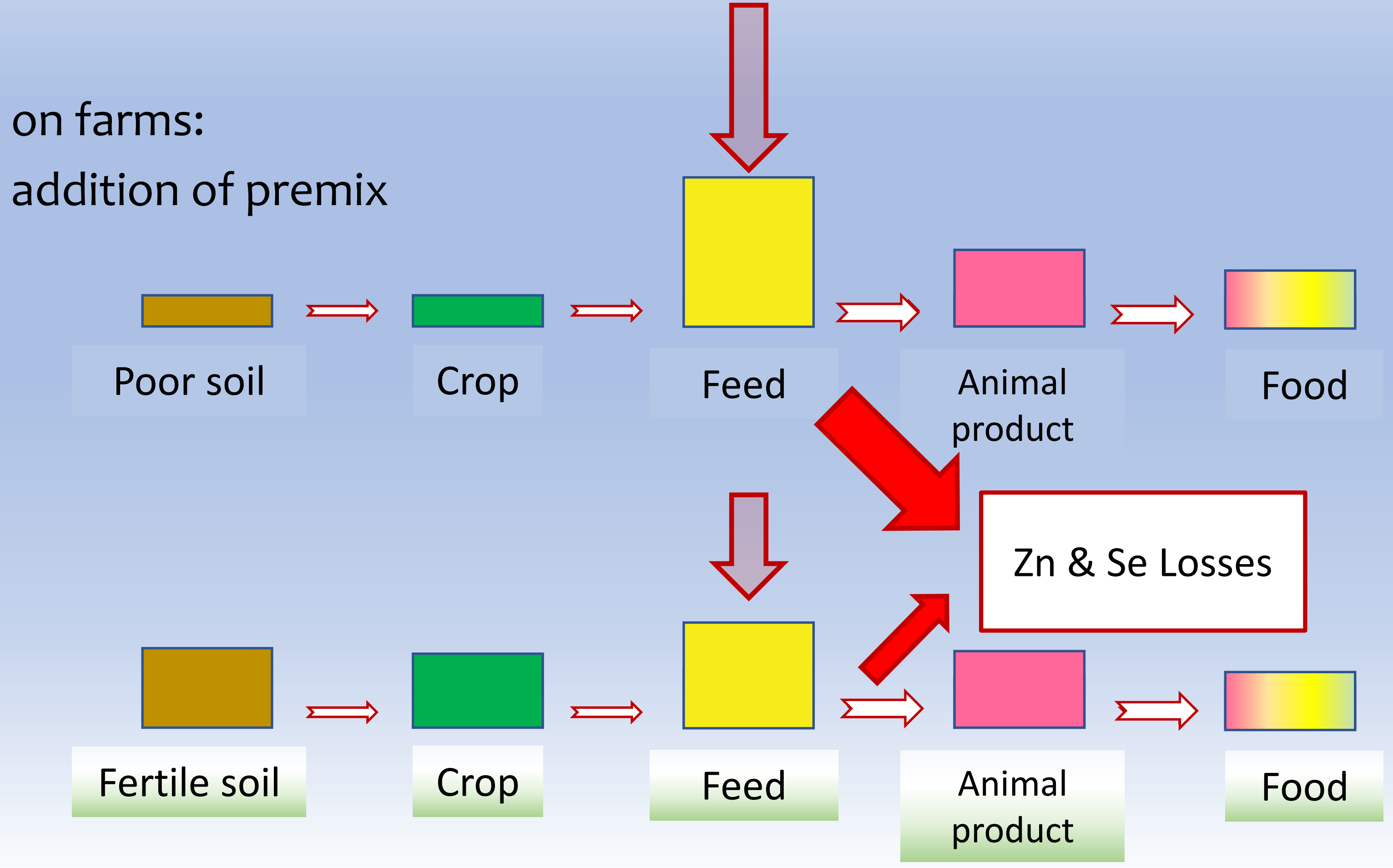
- Foliar application of Se (10; 20 i 30 g/ha) and cobiofortification with Se (30 g/ha) and Zn (6 kg/ha)



- *Successful increase of Se concentration in sunflower grain.*
- *Increase in concentration 11-32 times*
- *Concentration above 300 µg/kg after addition of 10 g/ha Se (it would be enough to apply 6 g/ha Se).*
- *Great potential for the production of enriched oil and enriched feed mixtures*

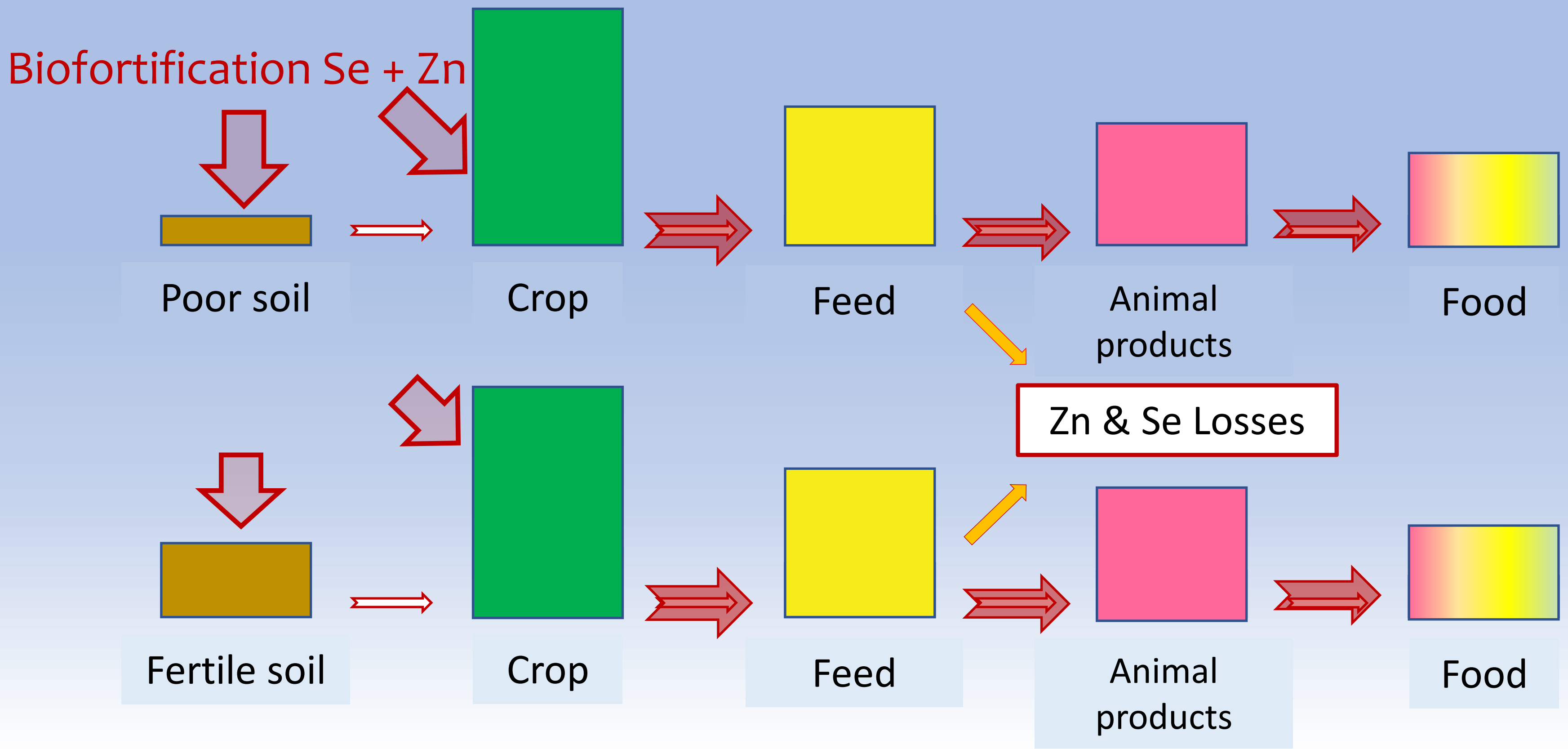
V. Biofortification of animal products (eggs)

- Why?



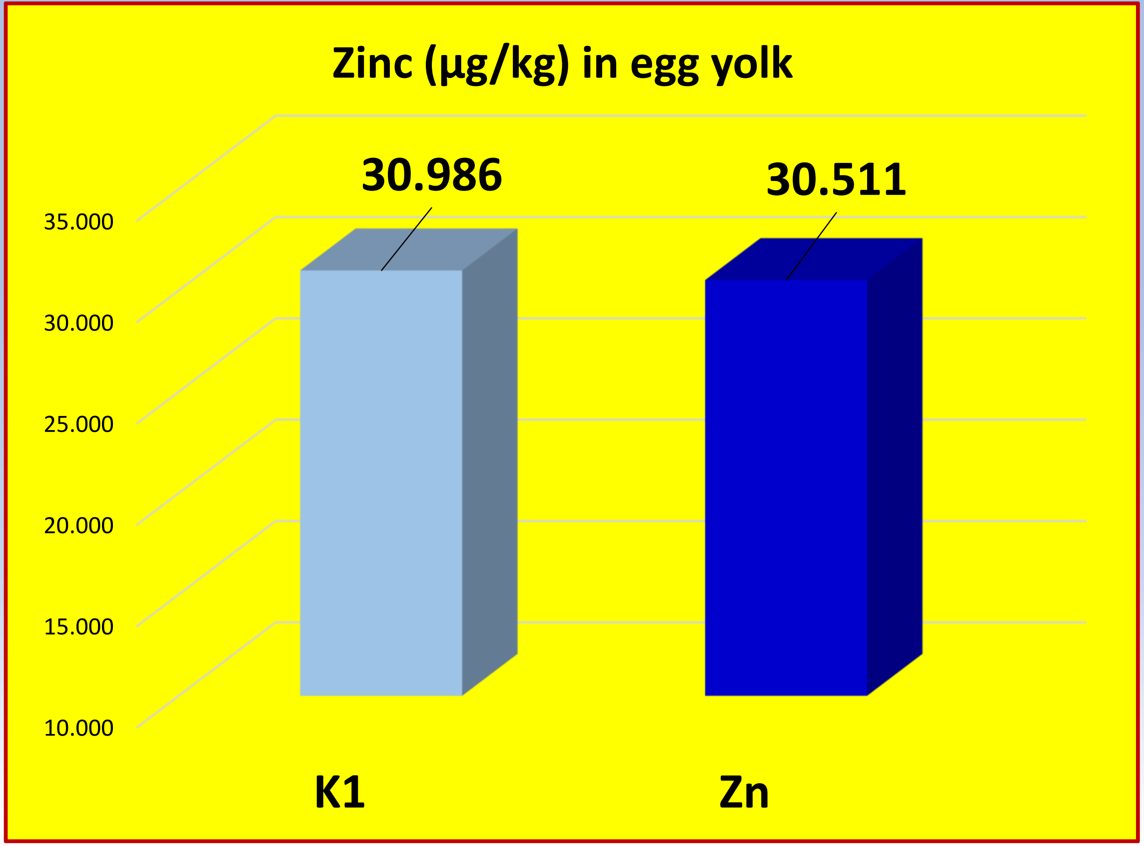
V. Biofortification of animal products (eggs)

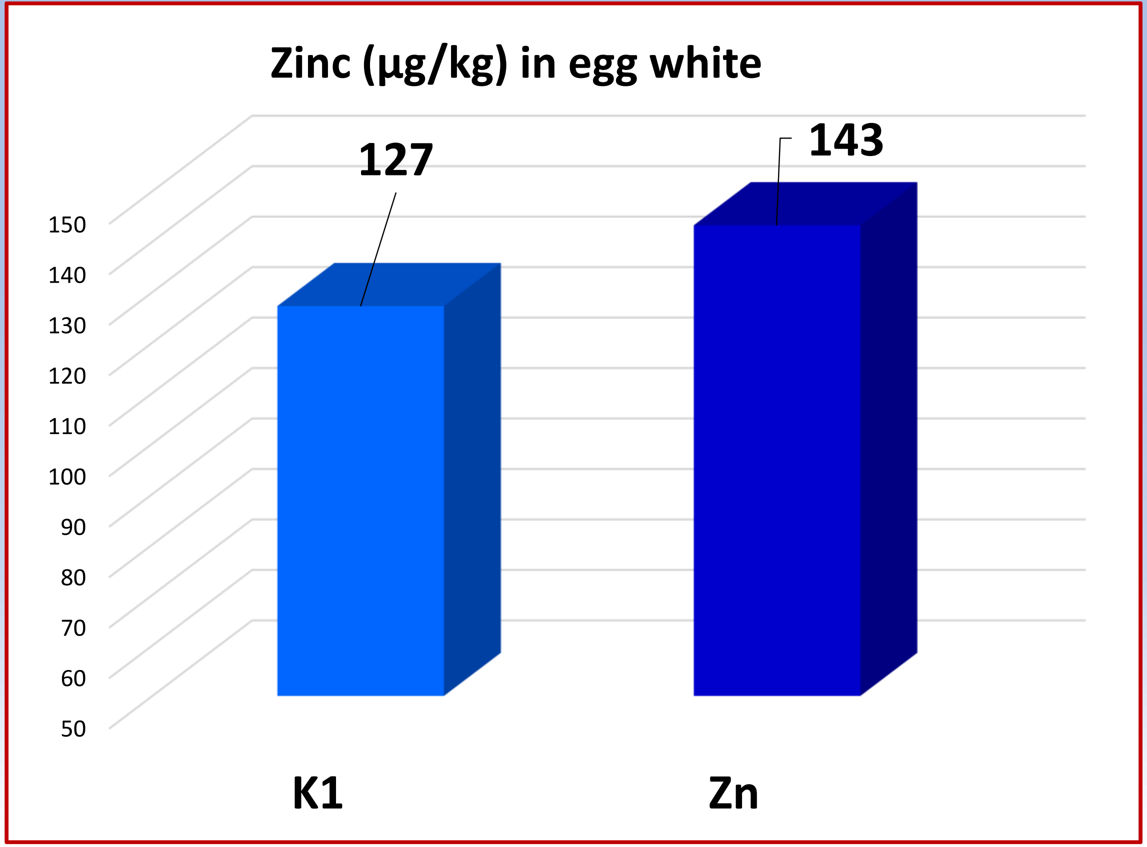
- To prepare the mixture for feeding laying hens, instead of Se and Zn mineral as supplements, corn, soybean and sunflower grains biofortified with Se and Zn were used



V. Biofortification of animal products (eggs)

- Zn in egg yolk not increased, in egg white Zn increased 12,6 %

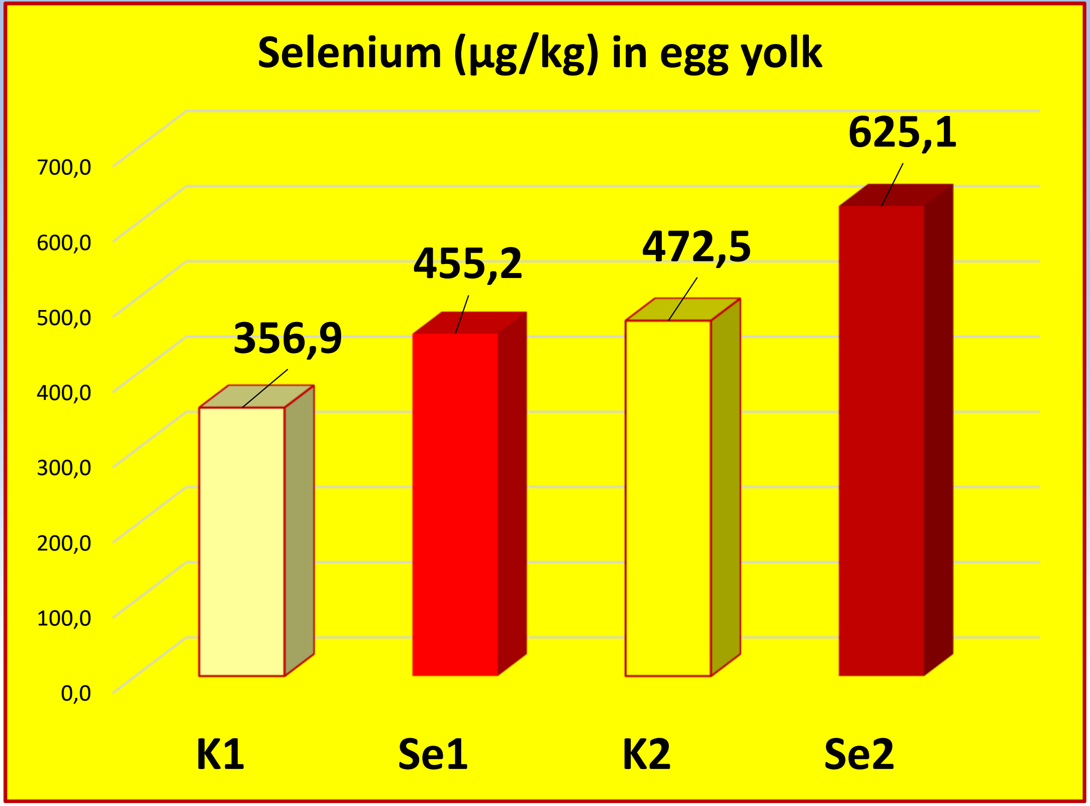


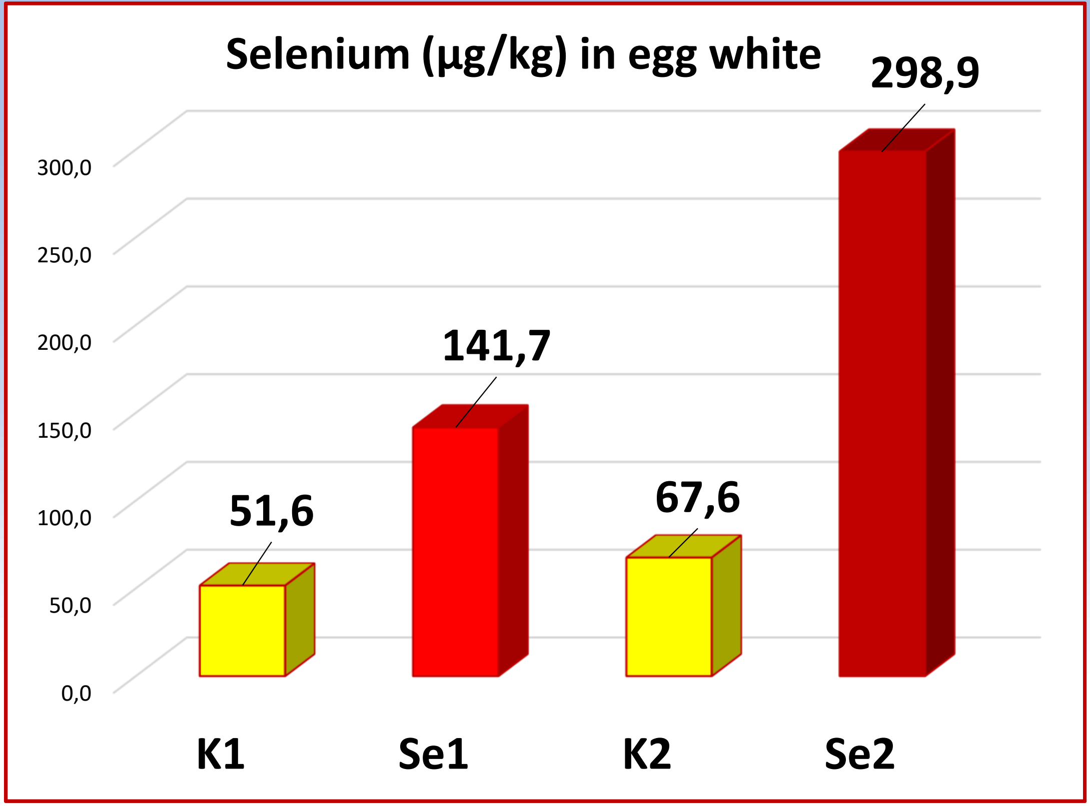


V. Biofortification of animal products (eggs)

Eggs with higher Se concentrations produced

- Se in egg yolk increased 27-32 %, in egg white 174 -342 %
- In total 46-71 % higher Se content





Feed biofortification

- Silage corn biofortification

Effect of different doses and application methods of sodium selenate on selenium status in silage corn

Biofortification with 20 g/ha Se (foliar application) resulted in Se concentration in silage corn increased from 18-20 µg/kg to 249 and 343 µg/kg (12.5 to 19 times). Soil application of Se was less effective.

AGRICULTURAL AND FOOD SCIENCE

E. Džomba et al. (2018) 27: 255–263

Effect of different doses and application methods of sodium selenate on selenium status in maize for silage

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A two-year field study was conducted to determine the effect of different Se fertiliser application methods and application rates on the selenium content in maize plants. Selenium as sodium selenate was added into soil (10 g and 20 g Se ha^{-1}) or sprayed on maize plants (20 g Se ha^{-1}). Maize plants from control treatment contained 0.018 and 0.020 mg Se kg DM^{-1} in the first and the second year of the study. Foliar application exhibited superior effect by increasing selenium content in the plants up to 0.343 mg kg DM^{-1} in the first year, and 0.249 mg kg DM^{-1} in the second. Soil selenium application was less effective; selenium content in maize plants varied from 0.018 to 0.019 mg kg DM^{-1} in the first and from 0.018 to 0.145 mg kg DM^{-1} in the second year, respectively. Strong linear correlation (r=0.71) was found between selenium content in the plants and in grains. Selenium recovery rates were significantly higher in case of foliar treatment compared to soil application.

Key words: selenium, foliar, soil, application, hybrids

Vegetable biofortification

- biofortification of leafy vegetables with Se

Combining Selenium Biofortification with Vermicompost Growing Media in Lamb's Lettuce (Valerianella locusta L. Laterr)

agriculture

MDPI

Article

Combining Selenium Biofortification with Vermicompost Growing Media in Lamb's Lettuce (*Valerianella locusta* L. Laterr)

Lucija Galić [1,*], Marija Špoljarević [1], Alicja Auriga [2], Boris Ravnjak [3], Tomislav Vinković [3] and Zdenko Lončarić [1]

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Biofortification with Se (application in vermicompost mixture) resulted in increasing Se concentration in Lamb's Lettuce that only 50 g of fresh leaves contain enough Se for recommended daily intake.

Abstract: Leafy vegetables are a daily part of the human diet all over the world. At the same time, a worldwide problem of Se malnutrition is present in human populations, mostly due to low soil Se contents. As plants represent the main source of this element in the human diet, with Se being an essential trace element for humans and animals, plant foods containing Se can be used as an efficient means of increasing the Se in the human diet, as well as in animal feed (biofortification). At the same time, the production of growing media relies on limited peat reserves. The use of earthworms facilitates the production of composted organic masses mostly consisting of organic waste, called vermicompost. The aim of this study was to investigate the influence of three different growing media (commercial peat media, vermicompost, and a 1:1 mixture) on Se biofortification's efficacy and yield in lamb's lettuce. The Se biofortification was performed with sodium selenate (Na_2SeO_4). It was shown that biofortification increased the Se contents such that a mass of only 48.9 g of fresh leaves contained enough Se for the recommended daily intake in human nutrition (55 µg Se/day), which represents a significant potential for solving Se malnutrition. Furthermore, the use of a 1:1 vermicompost–commercial substrate mixture showed a similar performance to the peat growing medium, contributing to the preservation of peat reserves.

Biofortification impact on environment

- Selenate and selenite impact
  Effect of different forms of selenium on the plant–soil–earthworm system

J. Plant Nutr. Soil Sci. 2017, 000, 1–10 DOI: 10.1002/jpln.201600492 1

Effect of different forms of selenium on the plant–soil–earthworm system

Ivna Štolfa[1], Mirna Velki[1]*, Rosemary Vuković[1], Sandra Ečimović[1], Zorana Katanić[1], and Zdenko Lončarić[2]

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Abstract

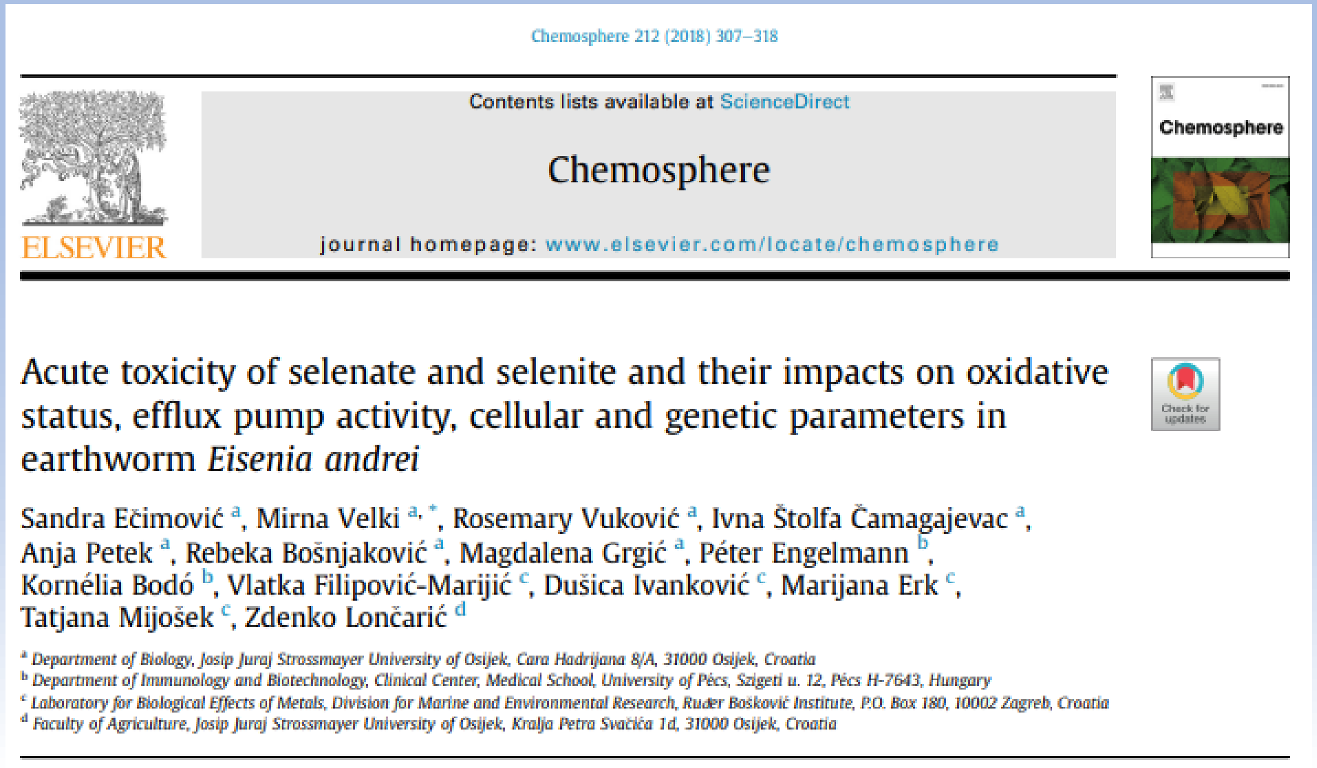
Selenium (Se) is an essential micronutrient for humans, animals, and certain lower plants, but at higher concentrations Se becomes toxic to organisms. The boundary between the Se beneficial effect and its toxicity is narrow and depends on its chemical form, applied concentration, and other environmentally regulating factors. Due to the potential risk of toxicity in higher concentration, the aim of this study was to estimate the impact of increased concentrations of different forms of Se on the response of the wheat–soil–earthworm system. Soil, earthworms, and wheat grains were exposed to the Se in form of selenite and selenate in concentrations of 0.01, 0.1, and 1 mg kg^{-1}. As an indicator of oxidative stress in wheat, lipid peroxidation levels (LPO) and total H_2O_2 content were determined, while antioxidative response was determined by catalase (CAT), glutathione peroxidase (GPX), and glutathione reductase (GR) activities. The biomarker

Both Se forms did not cause significant changes in the LPO level and H_2O_2 content, while GPX activities were elevated, suggesting that oxidative stress was not induced in wheat. In earthworms, Se significantly reduced activities of AChE and CAT, while carboxylester-ase (CES) activity was increased at all concentrations applied. This study showed significant impact of Se on measured biochemical responses in wheat and earthworms, indicating the disruption of homeostasis.

Biofortification impact on environment

Selenate and selenite impact on *Eisenia andrei*

Acute toxicity of selenate and selenite and their impacts on oxidative status, efflux pump activity, cellular and genetic parameters in earthworm Eisenia andrei



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journal homepage: www.elsevier.com/locate/chemosphere

Acute toxicity of selenate and selenite and their impacts on oxidative status, efflux pump activity, cellular and genetic parameters in earthworm *Eisenia andrei*

Sandra Ečimović [a], Mirna Velki [a, *], Rosemary Vuković [a], Ivna Štolfa Čamagajevac [a], Anja Petek [a], Rebeka Bošnjaković [a], Magdalena Grgić [a], Péter Engelmann [b], Kornélia Bodó [b], Vlatka Filipović-Marijić [c], Dušica Ivanković [c], Marijana Erk [c], Tatjana Mijošek [c], Zdenko Lončarić [d]

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[b] *Department of Immunology and Biotechnology, Clinical Center, Medical School, University of Pécs, Szigeti u. 12, Pécs H-7643, Hungary*
[c] *Laboratory for Biological Effects of Metals, Division for Marine and Environmental Research, Ruđer Bošković Institute, P.O. Box 180, 10002 Zagreb, Croatia*
[d] *Faculty of Agriculture, Josip Juraj Strossmayer University of Osijek, Kralja Petra Svačića 1d, 31000 Osijek, Croatia*

The assessment of acute toxicity showed a greater sensitivity of E. andrei to selenite exposure, whereas Se concentration measurements in earthworms showed higher accumulation of selenate form. Decrease in SOD activity and increase in lipid peroxidation and glutathione reductase activity indicate that Se has a significant impact on the oxidative status of earthworms.

Se impact on wild animals

Game feed with Se affects the concentrations of heavy metals in deer tissues

The effect of dietary selenium addition on the concentrations of heavy metals in the tissues of fallow deer (Dama dama L.) in Croatia

Environmental Science and Pollution Research
https://doi.org/10.1007/s11356-018-1406-7

RESEARCH ARTICLE

CrossMark

The effect of dietary selenium addition on the concentrations of heavy metals in the tissues of fallow deer (*Dama dama* L.) in Croatia

Neška Vukšić[1] · Marcela Šperanda[2] · Zdenko Lončarić[2] · Mislav Đidara[2] · Eyer Ludek[3] · Ivica Budor[1]

Received: 5 October 2017 /

Abstract
The aim of this research was to determine the concentrations of cadmium, lead, mercury, and arsenic and the essential elements iron and selenium in the tissues (muscle, kidney, liver, spleen, and fat) of fallow deer (*Dama dama* L.) without and with supplemental selenium addition. Another aim was to determine the effect of selenium addition on the indicators of oxidative stress, namely, the levels of superoxide dismutase, glutathione peroxidase, glutathione, and vitamin E. The research was carried out with 40 fallow deer during two research periods. Supplemental feed without selenium addition was provided during the first research period, and supplemental feed with added selenium (3 mg/kg) was provided for 60 days during the second research period. The concentration of selenium in tissues was higher in the second research period than in the first research period (in kidney tissue, 0.957 vs. 0.688 mg/kg, $P < 0.05$). The dietary addition of selenium decreased ($P < 0.05$) the concentrations of some heavy metals (lead in the spleen = 0.06 vs. 0.27 mg/kg and in the fatty tissue = 0.17 vs. 0.69 mg/kg; arsenic in the muscle tissue = 0.005 vs. 0.014 mg/kg, liver = 0.003 vs. 0.009 mg/kg, spleen = 0.004 vs. 0.013 mg/kg, and fat = 0.008 vs. 0.016 mg/kg). The activity of glutathione peroxidase was significantly higher ($P < 0.05$) in the second research period than in the first research period (1375.36 vs. 933.23 U/L).

The concentration of Se in tissues was higher after addition of dietary Se. The dietary addition of selenium decreased the concentrations of some detrimental heavy metals (Pb in the spleen and in the fatty tissue; As in the muscle tissue, liver, spleen, and fat).

Extruded Corn Snacks with the Addition of Zn and Se Biofortified Wheat

TEXTURAL AND SENSORY CHARACTERISTICS

processes

MDPI

Article

The Chemical and Rheological Properties of Corn Extrudates Enriched with Zn- and Se-Fortified Wheat Flour

Nikolina Kajić [1], Jurislav Babić [2], Antun Jozinović [2,*], Zdenko Lončarić [3], Leona Puljić [1], Marija Banožić [1], Mario Kovač [1], Dragana Šoronja-Simović [4], Ivana Nikolić [4] and Jovana Petrović [4,*]

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* Correspondence: ajozinovic@ptfos.hr (A.J.); jovana.petrovic@uns.ac.rs (J.P.)

Abstract: This paper analyzed the influence of the addition of Zn- and Se-fortified wheat flour to corn extrudates on viscosity, total starch content, starch damage, and bioavailability of zinc and selenium. Fortified wheat flour was added to corn grits in 90:10, 80:20, 70:30, and 60:40 ratios at three extrusion temperature profiles: 140/170/170 °C, 150/180/180 °C, and 160/190/190 °C. Viscosity values decreased significantly at different extrusion temperature profiles and at different proportions of wheat. The extrusion process increased the starch content, regardless of the extrusion temperature

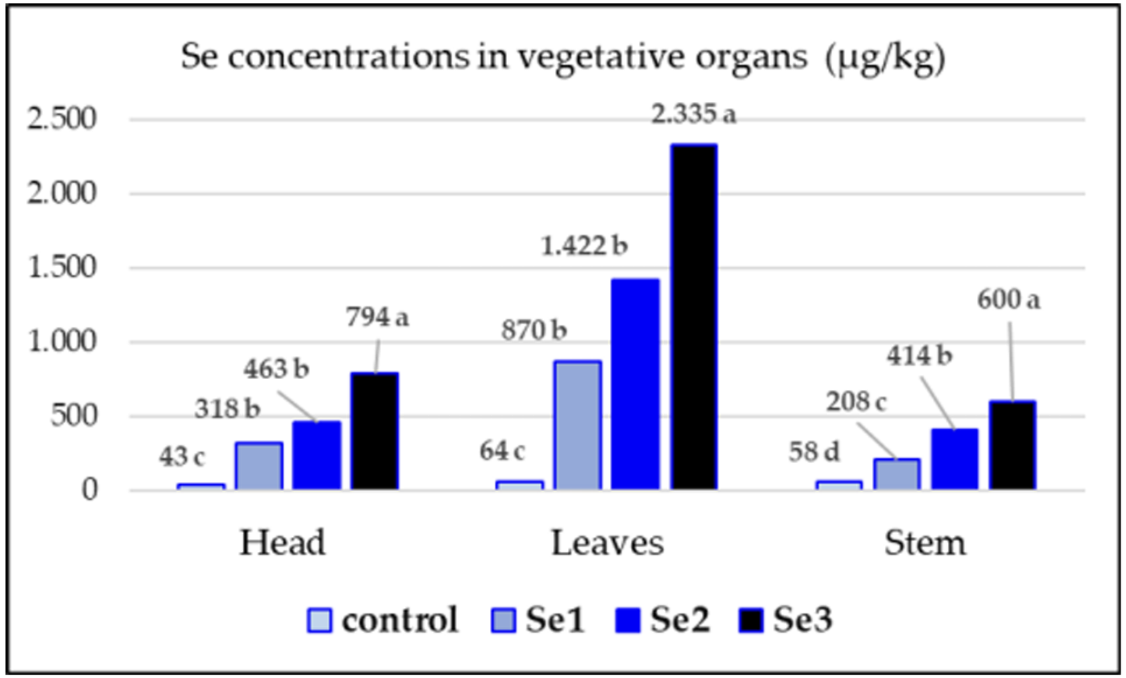
Flour of wheat biofortified with Zn and Se was added to corn grits at corn:wheat ratios 90:10, 80:20, 70:30 and 60:40.
Extrusion was performed at three temperature profiles: 140/170/170 °C, 150/180/180 °C, and 160/190/190 °C.

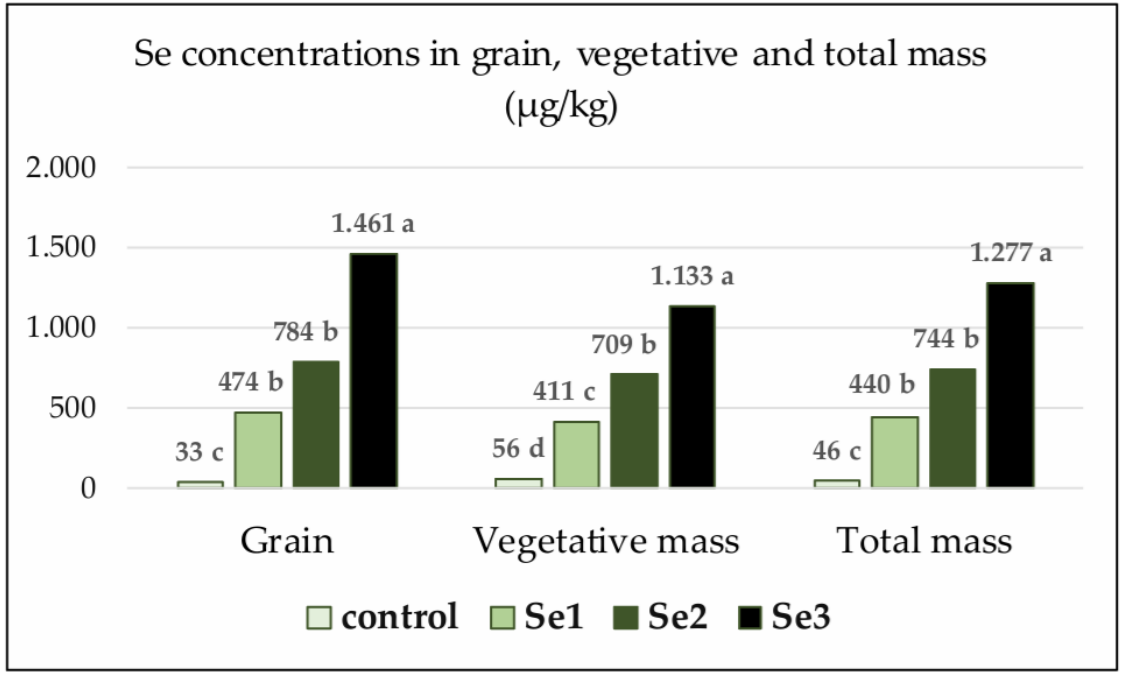
Zn increased from 3.07 to 23.01 mg/kg (increased 7.5 times).

Se increased from 21.89 to 304.48 µg/kg (increased 14 times).

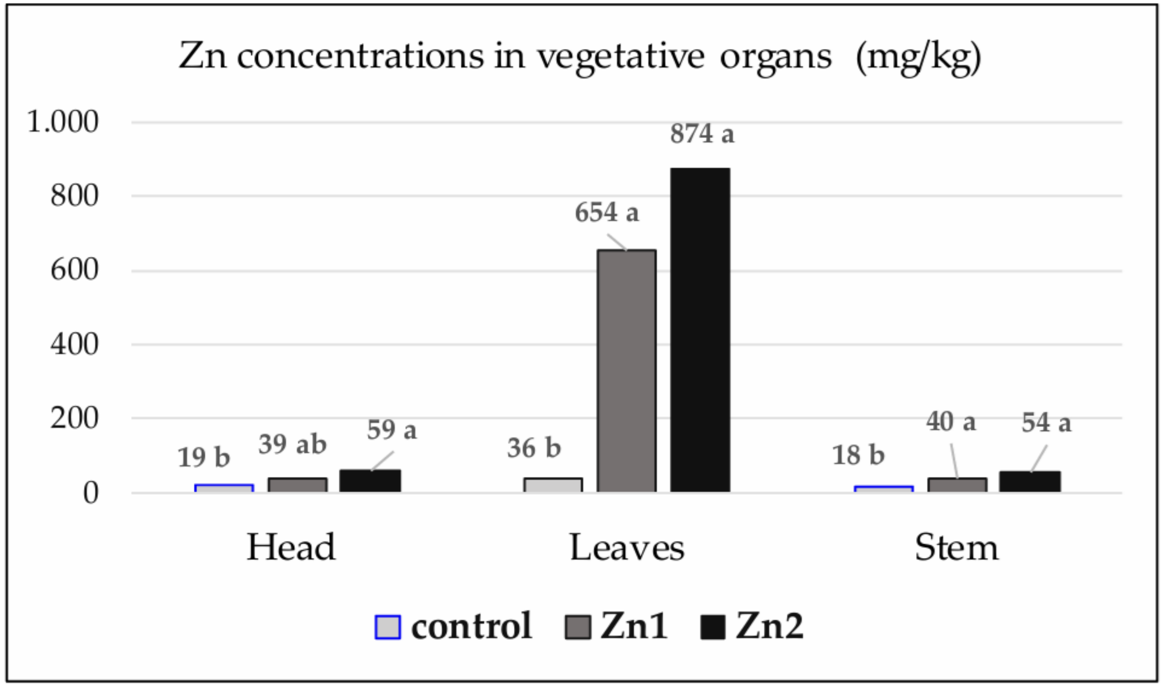
How the Biofortification of Sunflower can Result in the Enrichment of Vermicompost with Zn and Se?

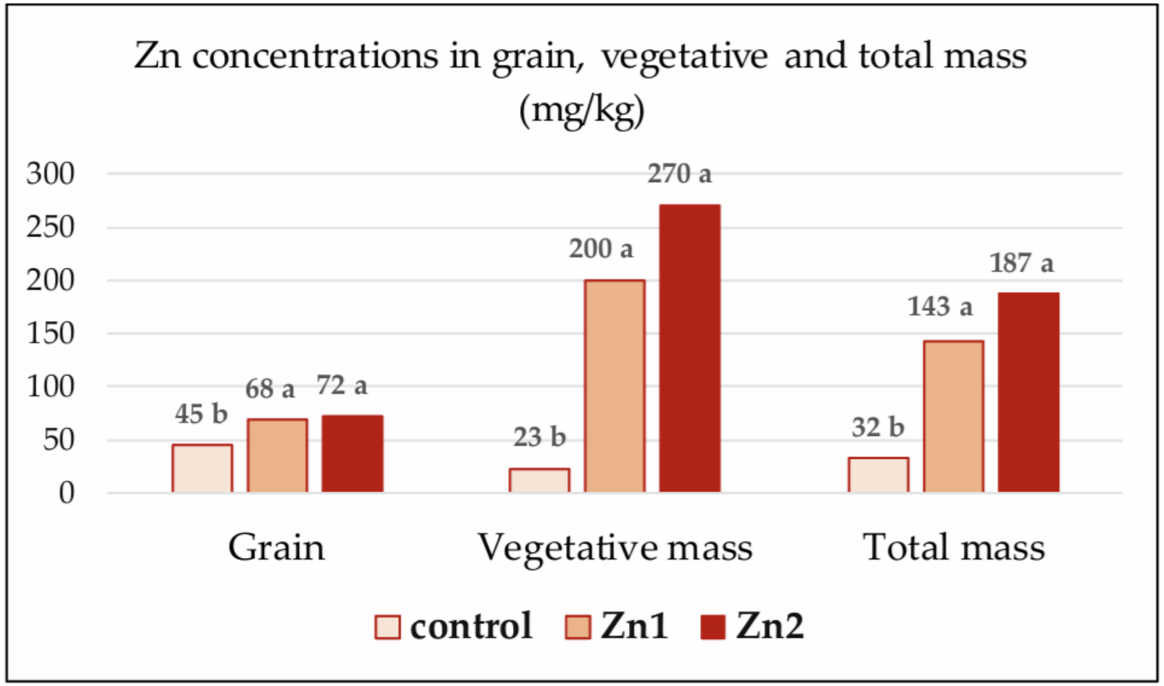
- Sunflower biofortified with Zn or Se
- Increased Zn and Se in grain and in harvest residues
- Harvest residues used for vermicompost production



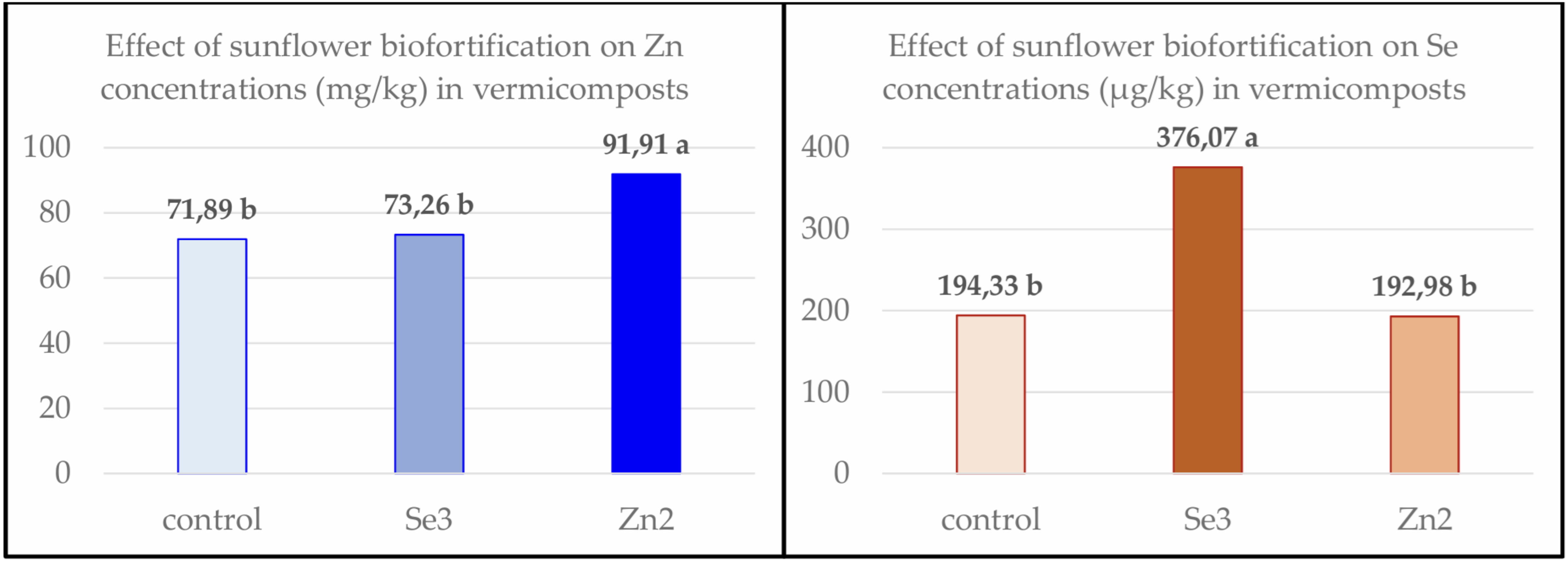


How the Biofortification of Sunflower can Result in the Enrichment of Vermicompost **with Zn** and Se**?**

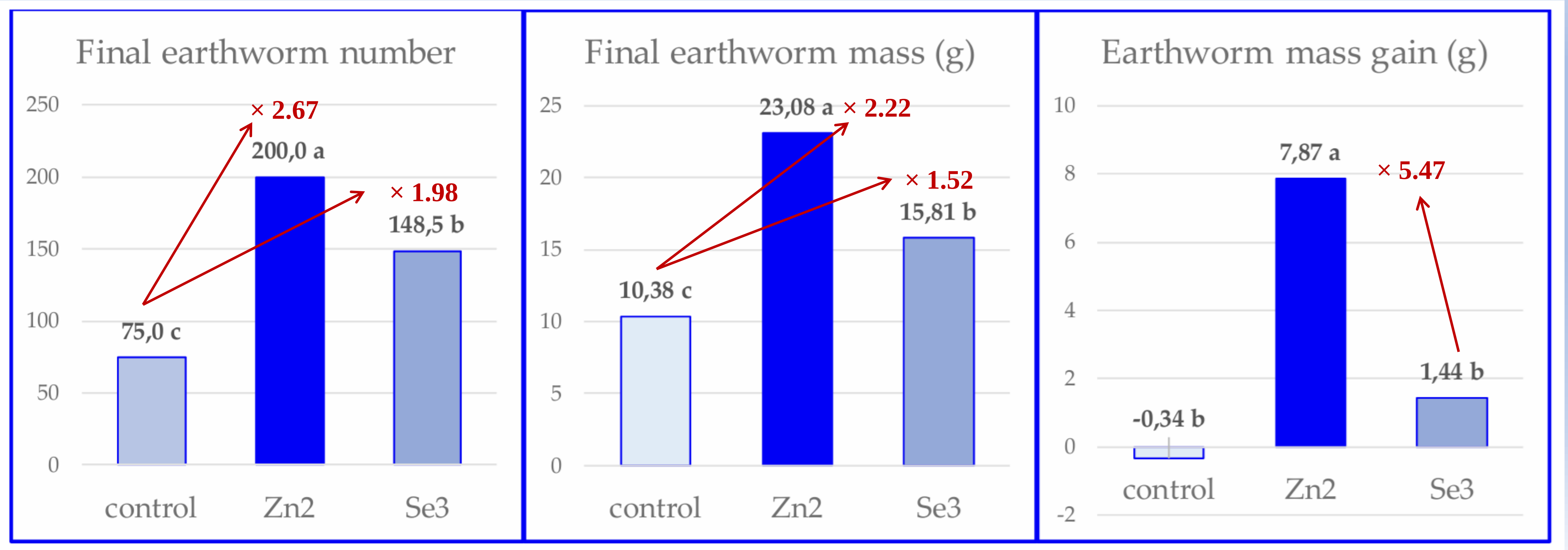




How the Biofortification of Sunflower can Result in the Enrichment of Vermicompost with Zn and Se?



Earthworms raction to Zn and Se?



Conclusions

Insufficient amounts and availability of microelements in soils (Se, Zn) result in insufficient (Se) or low (Zn) levels of microelements in food of plant origin

Biofortification is useful for mitigating malnutrition due to insufficient daily intake of microelements in food (in Europe Se, to a lesser extent Zn)

Biofortification with Se is very effective in all researched plant species, although no significant genotypic differences were found, and due to the diversity of the species, amounts of 5-30 g/ha of Se are required to achieve 300 µg/kg Se

Conclusions

The biofortification with Zn is of different efficiency, the highest in soybean, followed by sunflower and wheat, and the lowest in corn.

Enriched products of plant origin can be successfully used in the enrichment of products of animal origin.

Biofortification, especially Se and Zn, should be carried out with a systematic approach, taking into account all the needs of plants, animals and people and preserving the ecosystem.

Positive reaction of earthworms (Eisenia andrei) to harvest residues enriched with selenium and especially zinc.

Ongoing biofortifications…

Zn content in white wine (Žlahtina) increased ~20 %. Low content of detrimental HM.

Variability of barley cultivars, varibility in the malting process and in Zn and Se content in beer.

Small increasing of Se content.

Biofortifications by microbial bioagents…

Different combinations (mixtures) of microorganisms:

Maize:

- *Increasing Fe 91 %, Se 30 %, Zn 7 %, decreasing Pb 24 % and Cr 31 %*
- *Increasing Fe 21 %, Se 9 %, decreasing Pb 46 %, Cr 20 % and Cd 18%*
- *Increasing Fe 11 %, decreasing Pb 62 %, Cr 48 % and Cd 24 %*
- *No increasing, decreasing Se 22 %, decreasing Pb 36 %, Cr 19 % and Cd 47 %.*

Winter wheat:

- *Increasing Se 7 %, decreasing Pb 10 % and Cr 22 %*
- *Increasing Se 66 %, decreasing Pb 4 %, Cr 13 %*
- *Increasing Se 14 %, decreasing Pb 34 %, Cr 4 %*
- *No increasing, decreasing Cr 62 %, and Cd 17 %.*

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Faculty of Agrobiotechnical Sciences Osijek

Malnutrition and Crops Biofortification with Selenium and Zinc

Zdenko Lončarić, PhD, professor tenure
Josip Juraj Strossmayer University in Osijek
Faculty of Agrobiotechnical Sciences Osijek

Microbial bioagents:

Azospirillum brasilense
Azotobacter chroococcum
Azotobacter vinelandii

Bacillus thuringiensis
Bacillus megaterium
Bacillus subtilis

Pseudomonas putida
Pseudomonas fluorescens
Pseudomonas rhizosphaerae

Beauveria bassiana

Trichoderma harzianum
Trichoderma asperellum
Trichoderma koningii
Trichoderma viride
Trichoderma reesei

Endomycorrhizal fungi - genera Glomus and Gigasporae