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Effect of irrigation water containing iodine on quality of vegetable plants cultivated in greenhouse

Summary of the PhD thesis

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1. Introduction and purpose

Iodine is an essential element for the human body playing dominant role in the functioning of the thyroid gland. Currently, approximately 35% of the world's population is affected by iodine deficiency, which can cause several health diseases e.g. immune system weakness, mental and physical development problems [1-3].

The required iodine amount for the healthy functioning of the human body is only partially covered by food and drinking water, so additional resources are needed to supply this element [4,5]. Since the second half of the 19th century, many strategies have been used to solve this problem, applying iodized salt seemed to be an effective way, however, based on the directive of the World Health Organization the salt consumption should be reduced by 30% until 2025 for preventing the cardiovascular diseases [6,7], therefore other iodine enrichment approaches must be considered [8]. Iodine supplementation of irrigation water during plant cultivation seems to be an effective way because plants are able to accumulate the target element in the edible parts, and consumption of these enriched tissues could partially supply the daily recommended dietary allowance of iodine (150 μg) [9,10].

In my research work iodine accumulation and translocation processes of green bean, tomato, potato, cabbage, carrot and green pea plants cultivated in three different soils (sand, sandy silt, silt) were investigated by applying irrigation water containing iodine in concentration of 0.1 and 0.5 mg/L. During our experiments plant physiological properties (photosynthetic efficiency, chlorophyll concentration) biomass changes, as well as concentration changes of iodine and selected essential nutrient elements (boron, zinc, phosphorous, magnesium, manganese, copper, iron) were followed. The purpose of my work was to establish the influence of iodine treatment on the parameters listed above, furthermore, I also aimed to investigate the ability of plants for the iodine biofortification applying the selected experimental conditions focusing on the iodine accumulation of edible plant parts which can contribute or partially cover the recommended dietary intake of the target element for a normal adult person.

2. Materials and methods

Chemicals and analytical methods

The chemicals used in my work were of analytical grade. Ultrapure water (18 MΩ/cm) for dilutions and preparation of standard solutions was produced with a WasserLab Autwomatic device. NORMATOM 67% nitric acid and EMSURE 30% hydrogen peroxide solutions were applied for the digestion of plant samples. Potassium iodide was used for addition of irrigation water, and iodine stock solution for calibration was prepared using solid potassium iodate and, for the determination of selected essential nutrients, a multi-element standard solution was applied. Depending on the moisture content of samples, the plant parts were dried in a laboratory oven or lyophilized. The dried samples were digested by using a TopWave microwave-assisted digestion system. Concentrations of iodine and selected essential nutrients were quantified with a PlasmaQuant MS Elite inductively coupled plasma mass spectrometer The accuracy of the analytical methods was verified using NIST 1573a tomato leaf certified reference material. Statistical evaluation of the experimental results was calculated with R statistical software.

Characteristics of the soils used in plant cultivation

During the experiments sand (Mollic Umbrisol (Arenic), Őrbottyán), sandy silt (Luvic Calcic Phaeozem, Gödöllő) and silt (Calcic Chernoznem, Hatvan) topsoil (0-20 cm) types were used, and physical-chemical parameters are listed in *Table 1*. The pH was determined in a 1:2.5 soil:water suspension after mixing for 12 hours [11]. The organic matter content of the soil samples was determined using modified Walkley-Black method [12], and the calcium carbonate ($CaCO_3$) content was measured using the Scheibler method [11]. The bioavailable fraction of phosphorus and potassium was quantified by ammonium-lactate-acetic acid solution (AL) extraction [13], and the total nitrogen content of the soil was determined by the Kjedahl method [14]. Ammonium nitrogen (NH_4-N) and nitrate nitrogen (NO_3-N) concentrations were measured from KCl extract [15]. The cation exchange capacity (CEC) of soils was determined using the modified method of Mehlich [16]. The photosynthetic activity was determined by measuring the quantum efficiency of the II. photosystem (PSII) using an Os30p+ hand-held chlorophyll fluorometer. The chlorophyll content of the mature, youngest leaves was measured *in situ* with a CCM-200 plus chlorophyll content meter.

Parameters	Sand	Sandy silt	Silt
pH-H_2O	7.96	6.83	7.34
Organic material (w/w%)	0.91	1.24	2.12
$CaCO_3$ (w/w%)	1.45	0.08	0.20
Total nitrogen (w/w%)	0.064	0.092	0.135
NH_4-N (mg/kg)	1.4	2.3	3.9
NO_3-N (mg/kg)	4.7	2.3	14.2
AL-K_2O (mg/kg)	74	174	176
AL-P_2O_5 (mg/kg)	131	238	81
CEC (Na meq/100g)	9	17	37
Total iodine (mg/kg)	1.2	1.9	1.2

Table 1 Physical-chemical parameters of soils

Plant growth and iodine treatment

Green bean (*Phaseolus vulgaris* L. cv. Golden Goal), tomato (*Solanum lycopersicum* L. cv. Mano), potato (*Solanum tuberosum* L. cv. Balatoni rózsa), cabbage (*Brassica oleracea* L. var *capitata* cv. Zora), carrot (*Daucus carota* L. var. *sativus* cv. Nantes-2) and green pea (*Pisum sativum* L. var. Rajnai törpe) plants were grown in a greenhouse at the experimental station of HUN-REN Centre for Agricultural Research in Őrbottyán. The seeds were germinated for 3 weeks, then placed in plastic pots (size: 10L) containing cultivation medium (VEGASCA Bio; Florasca). The bottom of the pot was filled with gravel (4–8 mm), then it was covered with a fine synthetic fiber fabric on which the applied soil was layered in 10 kg of volume.

During the growing period, the plants were watered weekly with the mixture of drinking water/Hoagland nutrient solution and environmental parameters (temperature, humidity, light intensity) were continuously monitored. The drinking water used for irrigation in the experiment was stored in 0.5 m^3 tanks to reduce chlorine concentration. The seedlings were watered for 3 weeks with drinking water after irrigation with iodine containing water (0.1 and 0.5 mg/L) was started, which process was controlled with an automatic irrigation system.

3. Summary of new scientific results

1. Irrigation water containing iodine in concentration of 0.1 and 0.5 mg/L had no statistical influence on the plant physiological parameters (photosynthetic activity, chlorophyll content) of plants comparing with the control samples and it was established that iodine treatment had no negative effect on the healthy development of the investigated vegetables cultivated in three different soils.
2. It was demonstrated that iodine treatment (0.1 and 0.5 mg/L) didn't change significantly the dry mass of tomato and carrot plants cultivating in three soil types. Applying 0,5 mg/L iodine dosage in the irrigation water the biomass production decreased significantly in the following plant tissues: bean root (sand soil) and fruit (silt soil), potato root (sandy-silt soil) and tuber (silt soil), as well as in pea aerial part (sand soil). Irrigation water containing 0.1 and 0.5 mg/L iodine affected significantly positive the yield of cabbage leaves grown in sand and sandy silt soils.
3. It was presented that iodine treatment increased the target element accumulation in root, aerial part and edible tissues of all 6 vegetables cultivating in sand, sandy silt and silt soils comparing with the control samples, and in the most cases applying 0.5 mg/L iodine in the irrigation water the stimulation was significant.
4. Focusing on the quantification of selected essential nutrient elements it was established that irrigation water containing 0.1 and 0.5 mg/L iodine had different effects on these concentrations. Depending on the applied soil type and iodine concentration, the highest changes were observed in case of iron and the lowest for zinc, copper and boron.
5. Applying the mentioned experimental conditions, it was found that green bean, potato and green pea plants proved to be the least suitable target plants for the iodine biofortification, consuming 100 g of fresh vegetables from the edible parts of these plants only 11, 3 and 9 % of the daily recommended iodine intake could be covered, respectively.
6. It was demonstrated that cabbage was the most favourable target plant for the iodine supplementation, it was calculated that consuming 100 g of fresh leaf would cover 80% of recommended dietary allowance.

4. Conclusion

In my PhD work iodine biofortification of green bean, tomato, potato, cabbage, carrot and green pea plants cultivated in three different soils (sand, sandy silt, silt) were investigated. Target plants were irrigated with water containing iodine in concentration of 0.1 and 0.5 mg/L and during our experiments plant physiological properties (photosynthetic efficiency, chlorophyll content), dry mass and concentration changes of iodine as well as selected essential nutrient elements were followed.

Iodine treatment affected only moderately the photosynthetic efficiency and chlorophyll content of these plants comparing with the control samples, and the differences were not significant. Based on the experimental results, it can be established that the treatment had no negative effect on the health condition of the investigated leaf plant tissues.

Focusing on the biomass productions of tomato and carrot plants it was showed that iodine addition had no statistical impact on this parameter, the treatment didn’t influence the health condition of these target plants. It was demonstrated that applying 0.5 mg/L iodine treatment significant decrement was observed in the following plants parts: bean root (sand soil) and fruit (silt soil), potato root (sandy-silt soil) and tuber (silt soil), as well as in pea aerial part (sand soil). In contrary, the biomass production of cabbage plants cultivated in sand and sandy silt soil was stimulated significantly by the iodine addition.

Iodine containing irrigation water had positive effect on the target element accumulation in all plants cultivating in three different soils and in the most cases using iodine in concentration of 0.5 mg/L these changes were significant.

Irrigation water containing different iodine concentrations had various impact on the essential element transport of plants. It was demonstrated that the highest changes were observed in case of iron, while the lowest for zinc, copper, and boron comparing with the untreated samples.

It was reported that after the treatments potato was the least suitable vegetable, while cabbage seemed to be the best target plant for the biofortification with iodine.

5. References

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6. List of scientific publications

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Péter Dobosy, Viktória Vetési, Sirat Sandil, Anett Endrédi, Krisztina Kröpfl, Mihály Óvári, Tünde Takács, Márk Rékási, Gyula Záray: Effect of irrigation water containing iodine on plant physiological processes and elemental concentrations of cabbage (*Brassica oleracea* L. var. capitata L.) and tomato (*Solanum lycopersicum* L.) cultivated in different soils. Agronomy 10 (2020) 720.

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Scientific lectures directly related to the PhD thesis

Viktória Vetési, Mihály Óvári, Márk Rékási, Sirat Sandil, Gyula Záray, Péter Dobosy: Effect of iodine on the growth and elemental composition of bean and pea cultivated in different soils applying irrigation with KI containing water, XVII Italian-Hungarian Symposium on Spectrochemistry, (online), Torino, Italy, 14-18 June 2021.

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Supervisor activity

Co-supervisor

Kovács Vanda Viktória: Jód adagolás hatása fóliasátorban nevelt paradicsomnövények elemfelvételére, Eötvös Loránd Tudományegyetem, Természettudományi Kar, Tudományos Diákköri Dolgozat, 2020.

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Sirat Sandil, Mihály Óvári, Viktória Vetési, Péter Dobosy, Anna Füzy, Gyula Záray: Effect of arsenic in irrigation water on plant growth at different developmental stages, 16th Carpathian Basin Conference for Environmental Science (online), Budapest, Hungary 30 March- 1 April 2021.

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