THE CONTENT OF NUTRIENTS AND CONTAMINANTS IN SOIL AND VEGETABLES CULTIVATED IN SEVERAL GREENHOUSES FROM BOTOȘANI COUNTY AND THEIR IMPACT ON HUMAN HEALTH

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Abstract: Despite the fact that the fruits and vegetables consumption is generally associated with reduced risk of major diseases, in many cases their consumption is still below the dietary guideline goal. In order to evaluate the human health impact associated with vegetables consumption, it is vital to monitor the quality of the agricultural soil and the cultivated vegetables. The aims of the present study were: (1) to analyse the ions content in different vegetables, in the greenhouses soil on which the vegetables are grown and in the water used for irrigation; (2) to evaluate the ions distribution with the soil depth; (3) to evaluate the seasonal fluctuations of ions content in vegetables, greenhouse soils and irrigation water; (4) to investigate the transfer ratio of the analysed ions from soil to plant; and (5) to calculate the ions intake rate via vegetables ingestion. The most abundant ions present in soil solution were NO_3^- (0.06 – 5,619.30 mg/kg), Na^+ (0.02 – 437.97 mg/kg), SO_4^{2-} (0.06 – 390.93 mg/kg) and K^+ (0.024 – 337.05 mg/kg). Generally, the ions content slightly decreased from summer to autumn and decreased with the soil depth. With the exception of F^-, NO_2^- and NO_3^-, the ions content in the irrigation water was within the limits imposed by national legislation. The nitrate and nitrite intake caused by the ingestion of the analysed vegetables represents up to 2.15% and 9.05% from the adequate daily intake. The consumption of investigated vegetables provides relatively high intake of Cl^-, PO_4^{3-}, Na^+, K^+, Mg^{2+} and Ca^{2+}.

Keywords: Vegetables, soil, ions, human health, mineral intake;

1. INTRODUCTION

In many developed countries, the food security represents one of the primary concerns. The vegetables and fruits are important components in a healthy diet, because they are an important source of minerals (K, Ca, Mg, N, P, Mn, Fe, etc.), vitamins (A, B complex, C, E, D, K), antioxidants (ascorbic acid, carotenes, tocopherols, phenolic acids, flavonoids, sulphur antioxidants, etc.) and fibers (cellulose, hemicelluloses, pectins, lignin) (Vicente et al., 2009). Based on their adequate concentration for a normal tissue function, the minerals present in vegetables and fruits are generally classified as macronutrients and micronutrients (Vicente et al., 2009). The macronutrients present in plant tissues include K, Ca, Mg, N, P and S; they range between 1 and 15 mg/g dw (dw – dry weight) and they are absorbed by growing plant roots from soil solution as inorganic ions or oxides (Fageria & Baligar, 2004). Some of the nutrients maintain their identity as ions within plant tissues (K^+, Ca^{2+}, Mg^{2+}, etc.), while others (N, P, etc.) are assimilated into organic compounds (Fageria & Baligar, 2004; Vicente et al., 2009). The micronutrients essential in human diet include Mn, Cu, Fe, Zn, Co, Na, Cl, I, F, Se and their concentration in plant tissue is 100 to 10,000 times lower than those of macronutrients (Vicente et al., 2009). Generally, vegetables are a richer source of minerals than fruits. The majority of cations from the plant tissues are in the inorganic form, while the majority of anions are in the organic form (Fageria & Baligar, 2004). The organic ions are synthesized within the tissue and the inorganic ions are absorbed from the soil, the monovalent ions being absorbed faster than the polyvalent ions (Fageria & Baligar, 2004). Some nutrients are relatively immobile in plant tissues (Ca, Zn, B, Cu, Fe, Mn and Mo), while others are more mobile (N, P, K and Mg) (Fageria & Baligar, 2004).

There are different studies published in the international literature (Ruqia et al., 2015; Marles 2017; Mofor et al., 2017) which state that the mineral nutrient composition of fruits, vegetables and grains has decreased over the last 50 years. This is one of the consequences of intensive agriculture practices, which lead to the depletion of soil micronutrients. The deficiency of plant nutrients in the soil is a major problem, especially for rural communities where most of the inhabitants depend on agricultural production for their livelihood. In order to improve their agricultural yields, most farmers use fertilizers, which can lead to heavy metals, nitrate and nitrites contamination (Mofor et al., 2017). As a consequence, it is important to study the soil productivity and its quality as well. Soil quality is an integrative indicator of environmental quality, food security and economic viability (Jeffrey, 2000). Soil serves as a living environment for plants; therefore, its properties cannot be separated from the food quality or other factors of nutrition (Ghiula, 1966). The presence of sufficient amounts of nutrients in a soil does not guarantee their availability for the growing plants, which can be limited by factors like soil moisture, soil temperature, pH, soil salinity, etc. (Fageria & Baligar, 2004).

All of the above mentioned aspects emphasize the importance of monitoring the quality of the agricultural soil and the cultivated vegetables, in order to evaluate the human health impact associated with vegetables consumption. The aims of the present study were: (1) to analyse the content of anions (Cl^-, Br^-, F^-, NO_2^-, NO_3^-, PO_4^{3-}, SO_4^{2-}) and cations (Na^+, NH_4^+, K^+, Mg^{2+}, Ca^{2+}) in different vegetables (onion, cucumber, tomatoes, lettuce, eggplant, peppers), in the greenhouses soil on which the vegetables are grown and in the water used for irrigation; (2) to evaluate the distribution of anions and cations with the soil depth; (3) to evaluate the seasonal fluctuations of ions content in vegetables, greenhouse soils and irrigation water; (4) to investigate the transfer ratio of the analysed ions from soil to plant; and (5) to calculate the ions intake rate via vegetables ingestion.

2. MATHERIALS AND METHODS

The present study represents a continuation of a previous one, started in 2016, where it was investigated the nutrient content only in one soil profile, from those included in this article (Ispas et al., 2018).

The analysed vegetables were grown in greenhouses from a rural area located in Botoşani County (NE of Romania) and were distributed in the local markets from the County. The studied area is a greenhouses complex used to grow the vegetables for human consumption. The main activities in the area are the agricultural activities. After our knowledge, there is no similar study in the area reported in the literature.

2.1. Study area

The study was performed in a village from Botoşani County, northeast of Romania (Fig. 1).

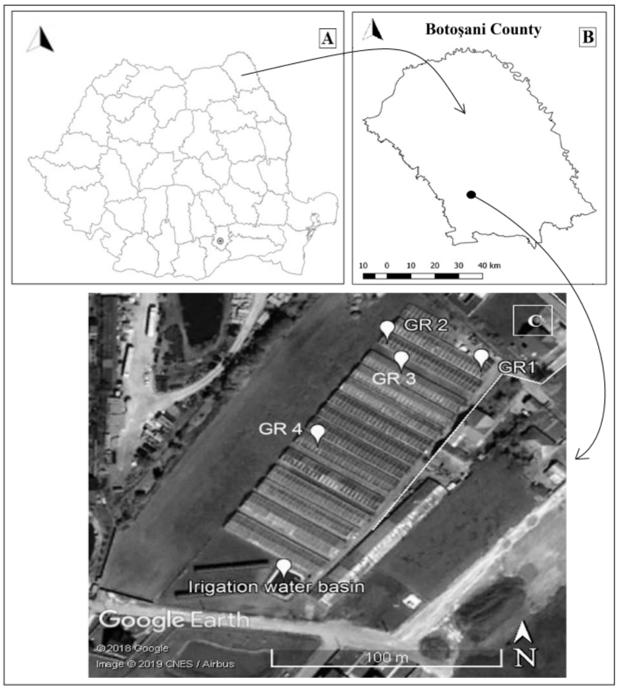

Figure 1. Location of the sampling area in the northeast of Romania (A), Botoşani County (B), with the investigated greenhouses GR1 – GR4 (C) (modified after Google Earth)

The village is dating back to 1361, it has a population of approximately 200 inhabitants (based on 2011 census) and it is located in a hilly area, on the site of ancient forests which were deforested.

The main activities in the area are the agricultural activities. The investigated area consisted in a complex of 17 greenhouses, four of these (GR1 – GR4) being selected for the current study. The following vegetables are cultivated and distributed in the local markets from the County: onion, cucumber, tomatoes, lettuce, eggplant and peppers.

From the geological point of view, the study area is part of the Moldavian Platform (between Siret and Prut rivers), and consists of Badenian, Sarmatian and Quaternary deposits. The Badenian formations, occurring on small areas, are represented by conglomerates, marls with gypsum and spheres of silex, marls and sandy clays. A large area is covered by the Sarmatian (Volhynian) deposits with sands, sandstones, limestones, oolithic limestones and microconglomerates into the western part and pelitic formations with gray clays in alternation with sandy deposits into the eastern part. The Quaternary deposits are represented by terraces and alluvial plains with gravels, sands and clays (Mihailescu & Grigore, 1981). Chemical composition of the Sarmatian sands consists mainly from SiO_2 together, in low amount, with Al_2O_3, Fe_2O_3, MgO, CaO, Na_2O, K_2O, TiO_2 (Petreuș et al., 1978; Petreuș et al., 1979).

Soils from Botoșani County are characterized by the cernozioms, especially along the main rivers (Prut, Bașeu and Jijia) and their tributaries. On the elevated terrains, covered by forests, the presence of podzols developed on the sands and clays deposits, corresponding to the wet and cold weather are present. Locally, on small areas, the presence of gleic and saline soils, with low fertility, was mentioned (EPA Botoșani, 2006). An important pedological study performed in Botoșani area (Mitoc) was the one made by Ștefan & Ștefan (2012), focused on phaeozem soil. In Romania, these types of soils are located mostly along the chernozems area, especially in sub-Carpathian regions and Moldavian Tableland (Ștefan & Ștefan, 2012). Because of their natural fertility, these soils present major agricultural interest. According to Ștefan & Ștefan (2012), the main characteristics of the investigated phaeozem soil are: loamy (medium) texture, thick Am horizon, moderate humus content, the absence of carbonates, a satisfactory content of micronutrients and potassium, a medium content of nitrogen and a very low content of phosphorus, which may impose the necessity of fertilization (Ștefan & Ștefan, 2012). The gleyic phaeozem from Botoșani area can offer very good conditions for a large assortment of agricultural crops (Ștefan & Ștefan, 2012).

2.1.1. Samples collecting, processing and analysis

In order to evaluate the seasonal fluctuations of the investigated parameters, the sampling was performed monthly during 2016 (June, July, August and October) and 2017 (January, March and April).

A total of 200 agricultural soil samples were collected from the four greenhouses. The vegetables were sampled simultaneously with soil samples, with the exception of January 2017, where there was no vegetation. A total of 34 vegetable samples were collected.

The water used for irrigation is extracted by four wells and stored in a pool in order to warm up from the sun. Water was sampled during June, July and August 2016, after this period the irrigation was not required because the rainfalls have provided sufficient soil humidity.

2.1.2. Agriculture soil

Soil sampling was performed according to national protocols (OM 278/2011), with a manually corer provided with an extension rod in order to carry out samples at eight depths (0 – 20 cm, 20 – 40 cm, 40 – 60 cm, 60 – 80 cm, 80 – 100 cm, 100 – 120 cm, 120 – 140 cm and 140 – 160 cm). Generally, the recommended sampling depths for analyzing the soil nutrient content are 15 – 20 cm (for immobile nutrients like Ca, Mg, etc.) and 60 cm (for mobile nutrients such as N) (Fageria & Baligar, 2004). In the present study, deeper soil sampling depths were selected in order to make a comparison between the nutrients content from the top soil (where fertilizers are applied) and the background level.

The soil samples were stored in sterile polythene bags, labelled, sealed, and transported to the laboratory in dark and cold (4°C) conditions.

The soil physical parameters were measured according to national protocols as follows: moisture (SR ISO 11465:1998), grain-size – sedimentation and sift method (SR EN 14688-2: 2005; SR ISO 11465:1998), organic matter (STAS 7107/1-76), bulk density – immersion in fluid method (ISO 17892-2:2014) and free swell index/adsorption capacity (IS-2720-PART-40-1970). The pH, electrical conductivity (EC) and salinity were measured in the aqueous extract of soil (5:1 ratio), using a portable multiparameter (WTW Multi 350i, Germany) (SR 7184-13/2001).

The dissolved ions were analysed in the aqueous extract of soil by using an adjusted method after Stanisic et al., (2011), by rotary mixer assistance extraction with deionized water (18.2 MΩ·cm at 25°C) in the ratio 5:1. The aqueous extract was then centrifuged, filtered (0.45 µm filters) and analysed by an ion chromatograph system (Dionex 1500 IC, USA). The ions content (mg/l) from the aqueous extract was then converted to mg/kg based on the soil mass and water volume used for the extraction.

According to the information provided by the producer, in the studied greenhouses, fertilizers are applied as fallowing: 200 kg/ha of manure during winter (November – December) and 200 kg/ha of chemical NPK fertilizer during spring (March).

2.1.3. Vegetables

After sampling, the damaged parts of the vegetables were removed and then the vegetables were washed with tap water and finally with distillate water. In order to extract the ion content from the vegetables, the samples were process according to an adapted method after Liu et al., (2016). Therefore, an amount of 5 g of fresh vegetable was ground with a mortar and pestle and then was put in a volumetric flask and diluted with aqueous solution of activated carbon (0.1 g/l) at a constant volume of 50 ml, then the samples were placed in an ultrasonic bath for 15 min and centrifuged for another 15 min (6,000 rpm) (Liu et al., 2016). The final supernatant solutions were filtered (0.45 µm) and analysed by ion chromatography.

2.1.4. Irrigation water

According to data provided by producer, during the short cycle (planting in June and harvesting in August or September) the irrigation water requirement ranged between 1,500 m^3/ha for lettuce to 3,500 m^3/ha for tomato. Water was applied by a drip irrigation system.

The water samples were collected in sterile containers and kept in the laboratory in dark and cold (4°C) conditions until the analysis. Water sampling was performed according to international protocols (ISO 5667-3:2018; ISO 5667-1:2006).

The physico-chemical parameters (pH, electrical conductivity, total dissolved solids – TDS and salinity) were measured *in situ* using a portable multiparameter (WTW Multi 350i, Germany).

The water samples used for the analysis of major dissolved ions were filtered (0.45 µm), kept in the refrigerator (at dark and 4°C) and analysed using an ion chromatograph system (Dionex 1500 IC, USA).

2.2. Transfer factor

In order evaluate the transfer of nitrite and nitrate from soil to plant, the transfer factor (TF) was calculated using the formula (1) (Harrison & Chirgawi, 1989; Sauerbeck, 1991; Intawongse & Dean, 2006; Uwah et al., 2009; Jolly et al., 2013):

$$TF = \frac{C_{plant}}{C_{soil}} \quad (1)$$

where: C_{plant} is the concentration of NO_2^- or NO_3^- in the plant material (dry weight basis); C_{soil} is the concentration of the same element in the soil (dry weight basis) where the plant was grown.

2.3. The ions intake rate via vegetables ingestion

2.3.1. The exposure to nitrate and nitrite via vegetables intake

The nitrate and nitrite contents from vegetables contribute to the dietary exposure to these chemicals. It is estimated that more than 80 – 95% of dietary intake of nitrate is attributed to vegetables consumption, especially green leafy vegetables (Reinik et al., 2008; Hord et al., 2009; Bahadoran et al., 2016). The exposure to nitrate and nitrite from vegetables can be assessed by calculating the daily intake (DI) and by comparing with the acceptable daily intake (ADI). The daily intake was calculated by multiplying the concentration of NO_3^- and NO_2^- from vegetables (mg/kg fresh weight) with the vegetable daily intake rate (kg/day) (EC, 1992; EC, 1997).

The European Commission’s Scientific Committee on Food (SCF) had established an ADI_NO_3^- (expressed as NO_3^- ion) of 0 – 3.7 mg/kg body weight (bw) (EC, 1992) and an ADI _NO_2^- (expressed as NO_2^- ion) of 0 – 0.06 mg/kg bw (EC, 1997). The Joint Expert Committee of the Food and Agriculture (JEFCA) of the United Nations/World Health Organization (WHO) have set in 2002 an ADI_NO_3^- of 0 – 3.7 mg/kg bw and an ADI_NO_2^- of 0 – 0.07 mg/kg bw (FAO/WHO, 2003; EFSA, 2008). These values correspond to 222 mg of NO_3^- per day and 3.6/4.2 mg of NO_2^- per day for an adult with a body weight of 60 kg.

2.3.2. The nutritive value of vegetables

Vegetables have a low energy value (between 10 and 50 kcal/100 g), but they represent an important source of minerals, particularly calcium, iron, and potassium (Lintas, 1992). Until recently, most studies were focused on single-mineral impact on human health, but the epidemiological surveys suggested that the combined constituents of a varied diet have a greater influence on human health than specific components do (Vicente et al., 2009).

In order to evaluate the nutritive value of the analysed vegetables, the daily intake of minerals was calculated and compared with the adequate intakes (AI) and the recommended dietary allowances (RDAs). The AI is considered to cover the needs of all healthy individuals in the groups, while the RDAs, represents the average daily dietary intake level sufficient to complete the nutrient requirements of nearly all (97 – 98%) healthy individuals in a group (Ross et al., 2011).

3. RESULTS AND DISCUTIONS

3.1 Physico-chemical parameters

3.1.1 Soil samples

The soil moisture ranged between 19.72 and 30.32% g/g, generally decreasing with the depth, while the bulk density (1.55 – 2.01 g/cm^3) increased with the soil depth (Table 1).

Generally, in the first layer (0 – 20 cm) the organic matter (OM) content was >5% and decreased with the depth. The distribution of clay (< 0.002 mm), silt (0.002 – 0.05 mm), sand (0.05 – 2 mm) and gravel (>2mm) fraction was investigated in the soil samples. The soil texture was dominated by clay fraction (21.49 – 75.85%), comparing to silt (9.63 – 30.76%), sand (5.61 – 55.94%) and gravel (0.00 – 14.08%) fraction (Table 1).

The soils proved to have a high adsorption capacity (80 – 110%), because of the abundance of clay fraction which retains high volumes of water due to the extremely small pore size, leading to a slow water migration.

The average level of pH ranged between 7.3 and 7.7, with no fluctuation with the soil depth (Fig. 2A). The results did not indicate a high spatial variability of pH, which was slightly lower in the soil from greenhouse 4.

The soil pH was generally higher during spring time and slightly decreased during the summer time. Based on national classification of agriculture soil (Dumitru et al., 2011), all the soil samples are classified as slightly alkaline, having the pH between 7.3 and 8.4. Such pH levels can be correlated with the presence of base cations like carbonates and bicarbonates, which are naturally present in the soil or in the irrigation water (McCauley et al., 2017).

The pH is an important soil parameter which controls the behaviour of different elements in the soil and can impact cation- and anion-exchange capacity by altering the charge on the soil colloids, or can influence nutrients availability or heavy metals absorption by plants (Kalev & Gurpal, 2017). Generally, the pH of agricultural soils ranges between 4 and 9; the optimum pH depends on the crop and soil type (Teaci, 1980; Fageria & Baligar, 2004). Generally, the legume crops grow in neutral or alkaline soils, while the grain and vegetable crops grow in soils with a pH between 5.5 and 7.0 (Kalev & Gurpal, 2017), indicating that the analysed soils samples had an optimum pH.

Table 1. The soil physical parameters.

	Soil depth (cm)	Clay (%)	Silt (%)	Sand (%)	Gravel (%)	Humidity (%)	Texture
Greenhouse 1	0-20	42.79	25.58	29.72	1.92	28.37	Sandy clay
	20-40	43.20	9.63	33.10	14.08	25.91	Clay
	40-60	44.80	21.46	33.59	0.16	26.24	Sandy clay
	60-80	49.88	17.97	32.15	0.00	27.32	Sandy clay
	80-100	41.89	30.76	27.35	0.00	25.62	Sandy clay
	100-120	39.07	28.78	32.03	0.12	23.80	Sandy clay
	120-140	37.09	30.76	32.15	0.00	24.23	Sandy clay
	140-160	40.29	24.36	35.34	0.00	24.14	Sandy clay
Greenhouse 2	0-20	33.89	23.5	38.48	4.12	30.32	Sandy clay
	20-40	39.07	19.93	40.86	0.14	24.68	Sandy clay
	40-60	48.00	20.37	31.42	0.22	24.33	Sandy clay
	60-80	48.67	19.92	31.25	0.16	23.11	Sandy clay
	80-100	45.47	18.32	36.13	0.08	22.41	Sandy clay
	100-120	51.86	11.93	36.21	0.00	23.90	Sandy clay
	120-140	52.60	26.86	20.54	0.00	24.78	Clay
	140-160	44.61	28.14	27.25	0.00	25.65	Clay
Greenhouse 3	0-20	46.20	20.97	31.50	1.32	29.20	Sandy clay
	20-40	53.46	15.77	30.77	0.00	25.86	Sandy clay
	40-60	74.25	20.14	5.61	0.00	23.45	Clay
	60-80	75.85	15.13	9.03	0.00	22.98	Clay
	80-100	35.88	15.31	48.81	0.00	21.07	Sandy clay
	100-120	34.28	10.43	55.30	0.00	21.14	Sandy clay
	120-140	27.88	30.57	41.31	0.24	23.59	Sandy clay
	140-160	35.87	19.38	44.75	0.00	22.07	Sandy clay
Greenhouse 4	0-20	40.67	23.53	35.31	0.48	26.78	Sandy clay
	20-40	39.07	22.57	38.35	0.00	22.61	Sandy clay
	40-60	43.87	25.77	30.36	0.00	25.59	Sandy clay
	60-80	40.67	25.77	33.51	0.04	22.01	Sandy clay
	80-100	34.28	27.05	38.67	0.00	19.72	Sandy clay
	100-120	29.48	23.53	46.98	0.00	20.10	Sandy clay
	120-140	40.67	25.77	33.55	0.00	20.45	Sandy clay
	140-160	21.49	22.57	55.94	0.00	21.70	Sandy clay

In the analysed soils, the electrical conductivity (EC) ranged between 233.50 and 869.67 µS/cm and the salinity ranged between 0.0 and 0.36 ‰ (Fig. 2A). For all the analysed soils, the EC was lower than 1,000 µS/cm, indicating that the soils are suitable for crop production (Horneck et al., 2011). The EC and salinity decreased with the soil depth, having the highest levels in the top soil (0 – 20 cm). The highest EC value was registered in greenhouse 2 (0 – 20 cm depth) and the lowest EC level was in the soil from greenhouse 4 (140 – 160 cm depth). The EC and salinity reflect the amount of dissolved salts in the soil solution, which have an important impact on plant growth, influencing the soil permeability, water uptake by plant, the soil productivity, the ion toxicity, the nutritional balance, etc. (Corwin & Lesh, 2003).

3.1.2. Vegetables samples

Generally, the analysed vegetables had a slightly acidic to neutral pH (exception for the tomato fruits) (Fig. 2B). Generally, the fruits were slightly acidic than leaves, with the exception of tomatoes, where the pH difference was more pronounced (Fig. 2B).

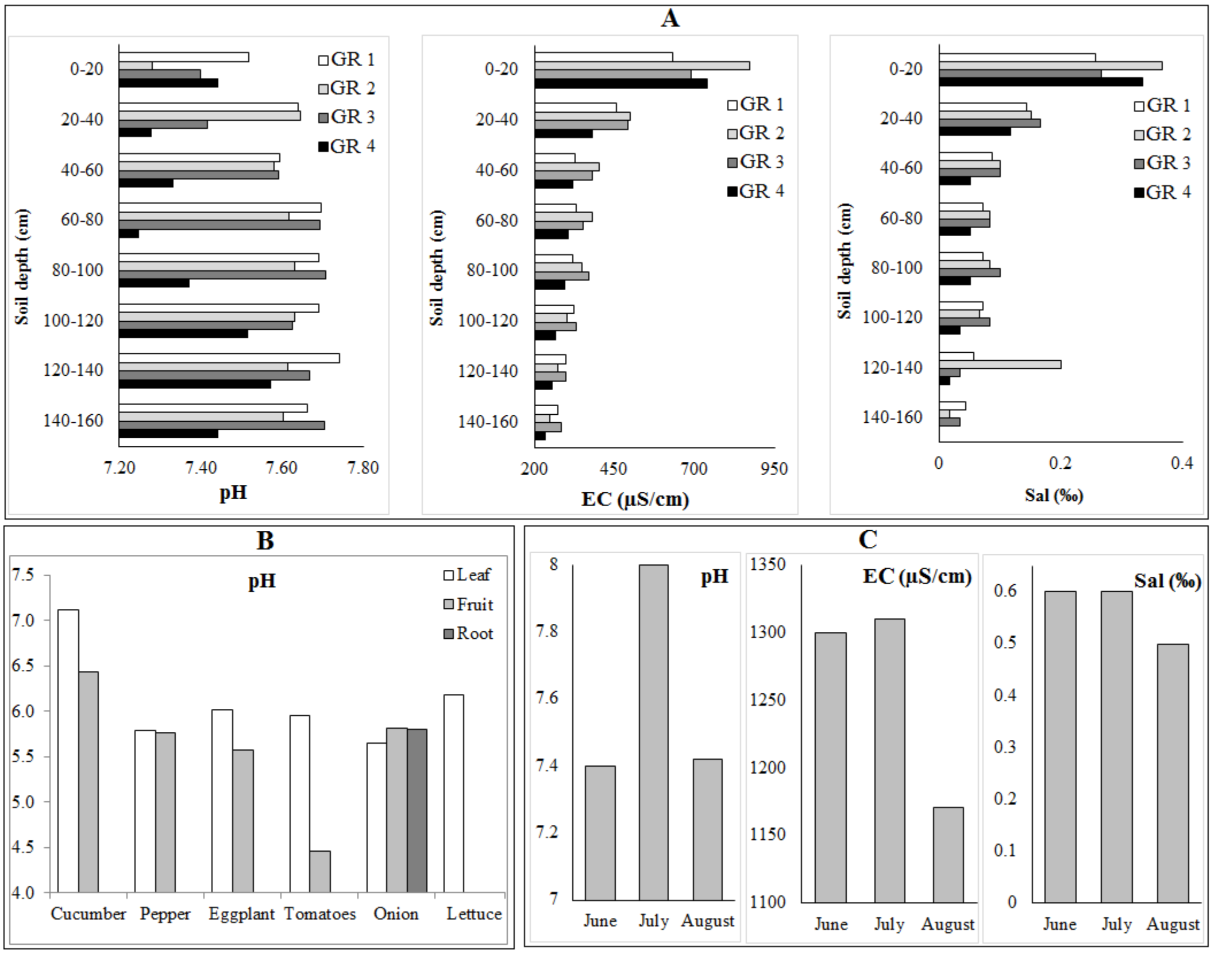

Figure 2. Physico – chemical parameters of soil (A), vegetables (B) and irrigation water (C) samples (GR – greenhouse; EC – electrical conductivity; Sal – salinity).

3.1.3. Irrigation water

The water used for irrigation was slightly basic having the pH between 7.4 and 8.0, registering higher values during July 2016 (Fig. 2C). The water pH was within the permissible limit (6.5 – 9.5) imposed by national legislation (Law no. 458 of 8 July 2002). The water used for irrigation had a relatively low level for EC (1,171 – 1,310 µS/cm), TDS (750 – 837 mg/l) and salinity (0.5 – 0.6‰), reflecting the content of dissolved salts. The water EC was within the limits imposed by national legislation (2,500 µS/cm) (Law no. 458 of 8 July 2002). The irrigation water was extracted from underground and deposited in an open pool. Due to the dilution process, caused by the higher amount of precipitations registered in August 2016, the EC, TDS and salinity levels were slightly lower during this period.

3.2. Dissolved ions content

3.2.1. Soil samples

The fluctuation of ions content along with sampling month and soil depth is presented in Fig. 3.

Generally, the ions content slightly decreased from June 2016 to October 2016, then a slightly increasing was registered (Fig. 3A). The average nitrate level was relatively constant, with the exception of March 2017, when the NO_3^- content was higher (Fig. 3A). This increasing could be correlated with the fertilizers application from the same period. Soils with high nitrate levels should be carefully monitored because nitrate ions readily move within the soil profile and can contaminate the crops or the groundwater (Lăcătușu et al., 2019; Domnariu et al., 2020). Further studies should be performed in the area in order to evaluate the possible impact of fertilizers application on groundwater quality.

The ions concentration decreased with the soil depth, especially between 0 and 60 cm (Fig. 3B), indicating the impact of fertilizers application on the natural composition of the soil and the distribution of humus and natural nutrients in the soil horizons.

The anions concentration was dominated by the presence of NO_3^- (0.06 – 5,619.30 mg/kg) and SO_4^{2-} (0.06 – 390.93 mg/kg), while the dominant cations were Na^+ (0.02 – 437.97 mg/kg) and K^+ (0.024 – 337.05 mg/kg).

Most plants utilize NO_3^- or NH_4^+ from the soil solution, the so called plant-available forms of nitrogen (McGrath et al., 2014). In the present study, the nitrogen forms identified in the soil solution were NO_2^- and NO_3^-. Nitrite content ranged between 0.06 and 17.67 mg/kg, with a monthly average level of 0.06 – 1.56 mg/kg (Fig. 3A) and an average depth level of 0.68 – 2.12 mg/kg (Fig. 3B). The ammonium content was below the detection limit, probably because it was readily nitrified to the nitrate form.

The sulphates content of the analysed soils (0.06 – 390.93 mg/kg) was considerably lower than the limits imposed by national legislation (OM 756/ 1997), which states an alert threshold for sensitive usage soils of 2,000 mg/kg. The average monthly level of SO_4^{2-} ranged between 76.7 – 167.36 mg/kg, corresponding to a SO_4^{2-}-S concentration in the soil solution of 8.54 – 18.60 mg/l SO_4^{2-}-S, which is higher than the level required for the optimum growth of most plants (3 – 5 mg/l SO_4^{2-}-S) (McGrath et al., 2014).

3.2.2. Irrigation water

The distribution of the dissolved ions in the irrigation water was dominated by the presence of SO_4^{2-} (130.14 – 137.71 mg/l), Na^+ (83.34 – 99.53 mg/l), NO_3^- (2.4 – 97.24 mg/l), Mg^{2+} (69.17 – 86.30 mg/l) and Ca^{2+} (54.18 – 85.03 mg/l) (Fig. 3C), comparing to Cl^- (46.95 – 49.67 mg/l), K^+ (21.76 – 27.18 mg/l), NO_2^- (0.02 – 22.64 mg/l) and F^- (1.1 – 1.29 mg/l).

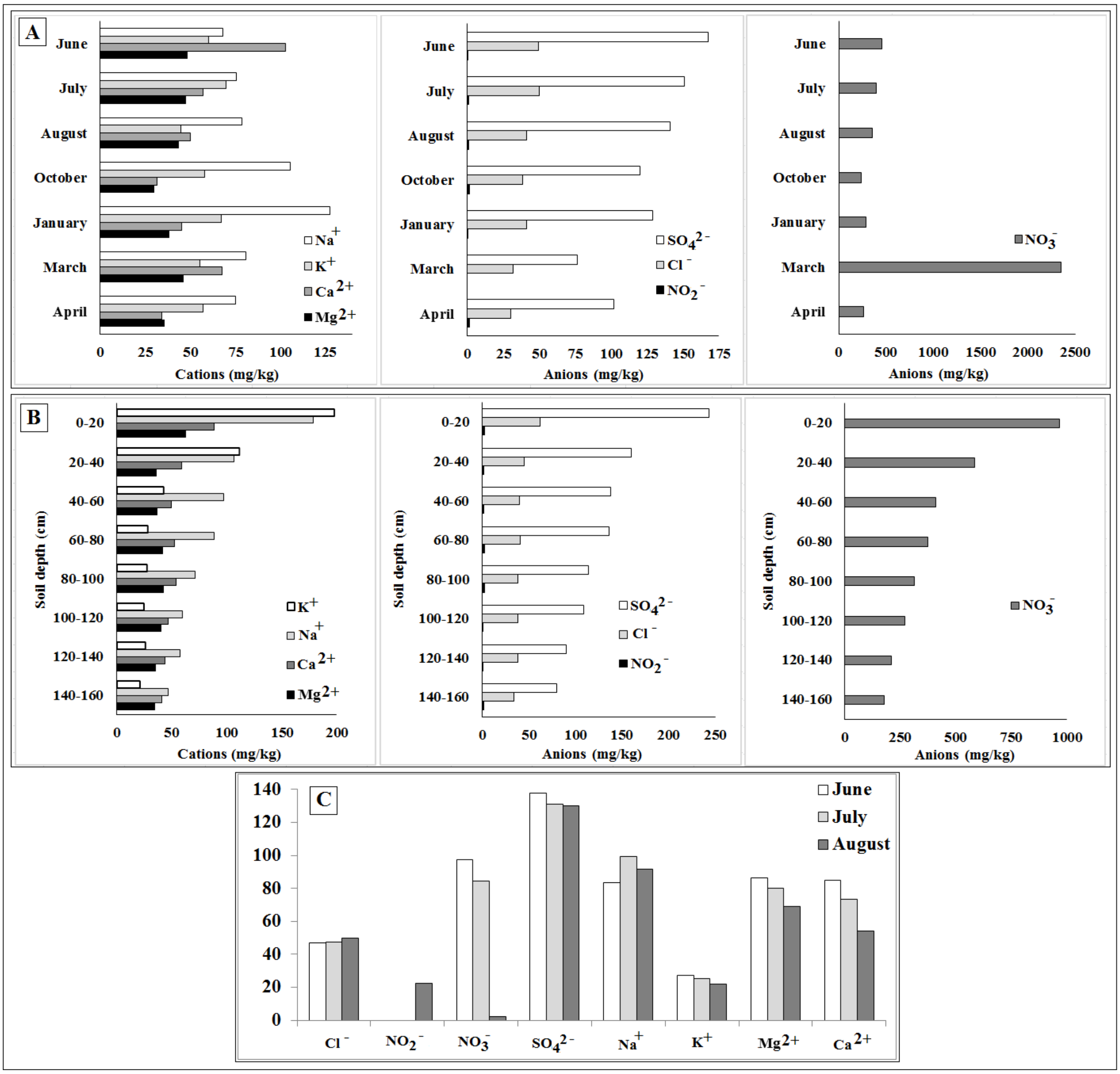

Figure 3. Average value of ions content in soil samples, depending on sampling month (A) and soil depth (B) and ions content in irrigation water (C).

Regarding the monthly fluctuation, there was a slight decrease in concentrations from June to July 2017 (exception for Cl^-, NO_2^- and Na^+) (Fig. 3C).

With the exception of F^-, NO_2^- and NO_3^-, the ions content is within the limits imposed by national legislation (Law no. 458 of 8 July 2002), which requires a maximum permissible limit of 1.2 mg/l (F^-), 50 mg/l (NO_3^-), 0.5 mg/l (NO_2^-), 250 mg/l (Cl^-), 200 mg/l (Na^+) and 250 mg/l (SO_4^{2-}). The NO_2^- content was below the detection limit (0.02 mg/l) in some months, while in August 2016 reached 22.64 mg/l, decreasing to 9.66 mg/l during September 2016 and being below 0.02 mg/l during October 2016. Such high fluctuations can be correlated with anthropic activities. Further attention should be paid on the content of nitrite and nitrate in the irrigation water, because the constant usage of water with high levels of NO_2^- and NO_3^- can be a contamination source both for agriculture soil and for crop.

Based on the Cl^- and SO_4^{2-} content, the water used for irrigation can be classified as water with a moderate saline residue (C2 class), having the Cl^- and SO_4^{2-} level up to 120 mg/l and 320 mg/l (Standard 9450-88). This type of water can be used for the irrigation of permeable soils and plants which are moderately tolerant to salinity (Standard 9450-88).

According to national legislation (Standard 9450-88), each class of salinity can be divided in three subclasses of alkalinity, based on sodium absorption ratio (SAR) level and sodium content.

The SAR level was calculated according to the following formula (Standard 9450-88):

$$SAR = \frac{c_{Na^+}}{\sqrt{13.187 \cdot c_{Ca^{2+}} + 21.746 \cdot c_{Mg^{2+}}}} \quad (2)$$

where, C_{Na^+}, $C_{Ca^{2+}}$, $C_{Mg^{2+}}$ are the ions concentrations (mg/l) in the irrigation water.

The SAR level ranged between 1.52 and 2.40, which corresponds to low alkalinity water (S1 subclass), having the SAR level up to 6.1. This type of water can be used for the majority of soil types (Standard 9450-88).

3.2.3. Vegetables samples

The ions distribution, expressed in mg/kg fresh weight (fw) in the leaf, fruit and bulb of the analysed vegetables is synthetised in Table 2. The ions content was higher in the leaves than in the fruits, because a large proportion of the micro- and macronutrients absorbed from the soil is translocated from roots to aboveground tissues and stored especially in the leaves. The nutrients can be also absorbed directly to the leaves due to particles deposited on the foliar surfaces. By comparing the nutrient content of the vegetable parts intended for human consumption, the cucumber fruits, tomatoes fruits and onion bulb proved to be rich in macro- and micronutrients (Table 2).

The highest levels of chlorine were registered in the eggplant leaf (950.8 – 1,097.1 mg/kg fw), tomatoes leaf (481.3 – 1,741.5 mg/kg fw) and onion, both leaf (219.6 – 1,855.0 mg/kg fw) and bulb (148.2 – 3,610.2 mg/kg fw) (Table 2). Chlorine has an important role in plants, being involved in plant energy reactions, moisture maintaining, drought and disease resistance, enzyme activation, or cation transport in plant tissues (McGrath et al., 2014).

The leaf of pepper and eggplant proved to have the highest levels of NO_2^- (0.2 – 1,378.1 mg/kg fw and 93.8 – 603.1 mg/kg fw), NO_3^- (245.1 – 580.0 mg/kg fw and 1,104.4 – 4,409.1 mg/kg fw) and PO_4^{3-} (82.2 – 1,997.7 mg/kg fw and 672.6 – 2,266.1 mg/kg fw). It is normal for leaves to have higher levels of nitrate than fruits, because nitrate accumulates mostly in the mesophyll cells of the leaves, being exclusively transported by the xylem (Pate, 1980; Zandstra, 1989). In the present study, with the exception of lettuce leaf, nitrite was not detected in any of the vegetables tissues destined for human consumption, reflecting that the used fertilizer was in adequate quantities so it does not affect the human health. The nitrite content in the analysed lettuce leaves range between 1.7 and 17.2 mg/kg fw, which is relatively similar to other studies reported in the international literature (Santamaria, 2006; Bahadoran et al., 2016). In the lettuce leaves collected in April 2017 from greenhouse 4, the nitrite content was higher (17.2 mg/kg fw). There are studies where nitrites level up to 30 mg/kg are reported in the leafy vegetables (Correia et al., 2010), even higher levels like 522 – 867 mg/kg (dry season) or 222 – 352 mg/kg (rainy season) in lettuce, 65 – 211 mg/kg (dry season) or 33 – 63 mg/kg (rainy season) in tomato and 544 – 700 mg/kg (dry season) or 232 – 376 mg/kg (rainy season) for onion (Akan et al., 2009). Generally, the leafy vegetables (lettuce, spinach, cabbage, rocket, etc.) tend to accumulate higher amounts of nitrite (Yosoff et al., 2015); they usually grow quickly and have high transpiration rates, which can enhance the roots uptake and the translocation of these elements to aboveground tissues. Leafy vegetables have shown a similar behaviour in terms of high ability to assimilate different elements present in soil, such as heavy metals (Roba et al., 2016).

The continuous consumption of high amounts of vegetables contaminated with nitrites can represent a risk for human health because of the potential reaction of nitrite with amines or amides to produce N-nitroso compounds which can be correlated to acute and chronic toxicities such as

Table 2. The ions content (mg/kg fw) in the analysed vegetables.

Vegetables		**Cl^-**	**NO_2^-**	**NO_3^-**	**PO_4^{3-}**	**SO_4^{2-}**	**Na^+**	**NH_4^+**	**K^+**	**Mg^{2+}**	**Ca^{2+}**
		(mg/kg fw)									
Cucumber (n=3)	Leaf	268.5 – 581.9 (427.1)[(a)]	0.2 – 115.5 (51.9)	16.1 – 380.0 (163.1)	0.2 – 0.9 (0.4)	637.6 – 2,160.1 (1,440.0)	13.9 – 28.6 (20.2)	0.1 – 1,634.7 (807.9)	1,405.3 – 2,369.7 (1,879.0)	471.1 – 929.5 (757.9)	380.6–602.8 (497.2)
	Fruit	178.2 – 240.7 (210.6)	< 0.2	2.0 – 365.6 (133)	114.1 – 246.2 (181.1)	114.1 – 246.2 (181.1)	15.5 – 44.1 (33)	0.1 – 326.8 (118.1)	1,297.5 – 1,481.3 (1409)	83.0 – 138.1 (108.3)	100.1 – 393.3 (244.0)
Pepper (n=3)	Leaf	170.7 – 226.2 (198.0)	0.2 – 1,378.1 (772.6)	245.1– 580.0 (442.5)	82.2 – 1,997.7 (900.1)	1284.4 – 2,195.4 (1,592.8)	0.2 – 184.0 (64.6)	0.1– 836.9 (279.0)	5,317.5 – 5,855.2 (5,605.2)	691.2 – 2,599.5 (1,703.9)	60.3 – 294.3 (162.2)
	Fruit	84.4 – 256.1 (159.5)	< 0.2	2.0 – 17.9 (8.2)	0.2 – 770.0 (281.5)	92.6 – 162.6 (118.4)	7.3 – 36.4 (17.1)	0.1 – 221.2 (79.7)	399.4 – 1,788.8 (1,132.6)	30.5 – 147.9 (87.5)	70.1 – 185.4 (143.7)
Eggplant (n=3)	Leaf	950.8 – 1097.1 (1024.0)	93.8 – 603.1 (348.5)	1104.4 – 4,409.1 (2,756.8)	672.6 – 2,266.1 (1,469.4)	512.2 – 582.5 (547.4)	27.1 – 55.2 (41.2)	0.1 – 1,051.0 (525.5)	4,202.9 – 6,013.3 (5,108.1)	359.3 – 1,400.3 (879.8)	196.6 – 440.6 (318.6)
	Fruit	76.4 – 295.9 (186.2)	< 0.2	0.6 – 7.0 (3.8)	78.9 – 393.2 (236.1)	33.2 – 113.4 (73.3)	6.5 – 11.3 (8.9)	<0.1	276.8 – 1,780.9 (1,028.9)	16.1 – 89.6 (52.9)	17.4 – 120.1 (68.8)
Tomatoes (n=3)	Leaf	481.3 – 1,741.5 (992)	0.2 – 102.7 (64.3)	0.2 – 501.7 (177.0)	0.2 – 670.9 (236.1)	1908.1 – 4,362.0 (2,982.0)	89.5 – 3,228.0 (781.2)	0.1 – 1,341.1 (447.1)	708.6 – 2,752.3 (2,010.0)	814.8 – 1,614.6 (1,189.2)	1,339.1 – 2,481.2 (1,738.5)
	Fruit	108.6 – 589.3 (318.5)	< 0.2	0.5 – 26.5 (9.9)	6.8 – 250.4 (144.7)	13.5 – 216.4 (96.1)	17.3 – 48.8 (30.7)	0.1 – 31.5 (10.5)	455.4 – 1,817.2 (1,175.6)	19.7 – 139.2 (73.9)	67.6 – 645.3 (281.5)
Onion (n=3)	Leaf	219.6 – 1,855.0 (1,037.3)	< 0.2	0.2 – 97.6 (48.9)	0.2 – 396.6 (198.4)	295.7 – 1,679.2 (987.5)	31.1 – 749.6 (390.4)	100.5 – 596.3 (348.4)	1,384.5 – 1,836.5 (1,610.5)	14.2 – 217.7 (116)	234.6 – 318.9 (276.8)
	Bulb	148.2 – 3,610.2 (1,879.2)	< 0.2	0.2 – 65.8 (33)	< 0.2	100.9 – 1,943.3 (1,022.1)	36.8 – 1,338.7 (687.8)	186.0 – 329.9 (258.0)	994.1 – 2,603.6 (1,798.9)	90.9 – 280.3 (185.6)	253.2 – 463.4 (358.3)
Lettuce (n=6)	Leaf	0.2 – 676.7 (421.4)	0.2 – 17.2 (6.2)	0.2 – 217.2 (49.7)	0.2 – 571.3 (145.2)	0.2 – 192.4 (114.7)	84.5 – 349.7 (233.0)	0.1 – 510.7 (154.1)	1308.5 – 3,705.5 (2,436.5)	24.7 – 300.1 (153.3)	205.8 – 627.7 (443.2)
MPL (EC No 1258/2011)[(b)]		-		5000/4000 mg/kg	-						

[(a)]*min – maxim (average);* [(b)] *MPL – maximum permissible limit (EC No 1881/2006) for lettuce grown under cover harvested between 1 October to 31 March (5,000 mg/kg) and between 1 April to 30 September (4,000 mg/kg)* methemoglobinemia, thyroid disorders and carcinogenesis (Fewtrell, 2004; Correia et al., 2010; Bahadoran et al., 2015).

The use of high amounts of nitrogen fertilizers can lead to nitrate accumulation in crops, because the uptake rate is higher than that of reduction and the plant cannot metabolize the absorbed nitrates (Lintas, 1992). Once ingested, nitrates can be reduced to nitrites, which react with secondary amines to produce nitrosamines under the influence of acids in the stomach (Lintas, 1992).

By comparing the nitrate level in the tissues designated for consumption, the data showed that the cucumber fruits contained higher nitrate amounts (2.0 – 365.6 mg/kg fw) (Table 2). The nitrate level in lettuce leaves (0.2 – 49.8 mg/kg fw) was considerably lower than the maximum permissible limits of 5,000 mg/kg (for lettuce grown under cover harvested between 1 October to 31 March) and 4,000 mg/kg (for lettuce grown under cover harvested between 1 April to 30 September) imposed by international legislation (EC No 1881/2006), indicating that its consumption is safe for human health.

The nitrate levels in the analysed vegetables is classified as very low (< 2,000 mg/kg fw) (Santamaria, 2006; Gorenjak & Cencič, 2013), being similar with those reported in some studies like Kmecl et al., (2017), or considerably lower than those reported in other similar studies, where NO_3^- content reached 4,488 mg/kg in lettuce (Chung et al., 2003).

High amounts of ammonium were identified in the leaf of cucumber (0.1 – 1,634.7 mg/kg fw), eggplants (0.1 – 1,051.0 mg/kg fw) and tomatoes (0.1 – 1,341.1 mg/kg fw).

Nitrogen is taken up by plants as NH_4^+ and NO_3^-, this element being found in chlorophyll, nucleic or amino acids, being included among the major components of proteins and enzymes which control different biological processes (McGrath et al., 2014).

The phosphate levels in the analysed vegetables (6.8 – 250.4 mg/kg fw in tomatoes, 0.2 – 396.6 mg/kg fw in onion leaf, 0.2 – 571.3 mg/kg fw in lettuce) was higher than those reported in other studies (Akan et al., 2009), where phosphate concentration ranged from 22 – 80 mg/kg (lettuce), 12 – 45 mg/kg (tomato), 21 – 35 mg/kg (onion) during dry season, while during the rainy season it ranged between 22 – 80 mg/kg (lettuce), 23 – 45 mg/kg (tomato) and 21 – 44 mg/kg (onion). It might be appropriate to use fertilizer with lower phosphorus content for the future.

Sulphur is taken up by plants as SO_4^{2-}, being involved in amino acids synthesis, enzyme development, chlorophyll synthesis, seed production and promotes nodulation in legumes (McGrath et al., 2014). The higher amounts of sulphates were recorded in the leaf of cucumber (637.6 – 2,160.1 mg/kg fw) and pepper (1,284.4 – 2,195.4 fw).

Being bivalent cations, calcium and magnesium were absorbed more slowly than the monovalent ions like potassium (Fageria & Baligar, 2004). Calcium is a nutrient which plays an important role in the cell elongation and division, being also involved in the activation process of several enzymes (McGrath et al., 2014).

Tomatoes leaf and onion bulb had the highest content of sodium (89.5 – 3,228.0 mg/kg fw and 36.8 – 1,338.7 mg/kg fw).

The leaf of pepper, eggplant, tomatoes and lettuce proved to have the highest content of potassium (5,317.5 – 5,855.2 mg/kg fw, 4,202.9 – 6,013.3 mg/kg fw, 708.6 – 2,752.3 mg/kg fw and 1,308.5 – 3,705.5 mg/kg fw). Among the analysed macronutrients, potassium had the highest concentration in plant tissue. This is a consequence of the fact that potassium is adsorbed by plants in higher amounts than any other essential nutrient, except for N (McGrath et al., 2014).

The highest levels of magnesium were identified in the leaf of cucumber (471.1 – 929.5 mg/kg fw), pepper (691.2 – 2,599.5 mg/kg fw), eggplant (359.3 – 1,400.3 mg/kg fw) and tomatoes (814.8 – 1,614.6 mg/kg fw). Magnesium is absorbed by plants as Mg^{2+} and it is the primary component of chlorophyll, having an important role if the photosynthesis process, enzyme activity and respiration process (McGrath et al., 2014).

3.3. Transfer factor (TF) of nitrate and nitrite from soil to vegetables

The TF for NO_2^- and NO_3^- varied between plant species and generally were higher in leaf than in fruit (Table 3).

Table 3. Transfer factor (TF)

Vegetable		TF_NO_2^-	TF_NO_3^-
Cucumber (n=3) [(a)]	**fruit**	-	0.18 – 14.03 (5.16)
	leaf	-	0.33 – 7.41 (3.98)
Pepper (n=3)	**fruit**	-	0.01 – 0.15 (0.07)
	leaf	-	2.79 – 5.79 (4.52)
Eggplant (n=2)	**fruit**	-	0.005 – 0.1 (0.03)
	leaf	196.30	10.9 – 45.4 (28.15)
Tomatoes (n=3)	**fruit**	-	0.008 – 0.38 (0.14)
	leaf	663.1	1.45 – 3.27 (2.4)
Onion (n=3)	**leaf**	-	0.2
	bulb	-	0.001 – 0.1 (0.027)
Lettuce (n=6)		22.3 – 65.26 (48.9)	0.4 – 4.1 (1.4)

[(a)] *n – number of samples;*[(b)] *min – maxim (average)*

The transfer factor for nitrate was generally low, being below 1 for most of the samples, which indicates that the vegetables did not accumulated important amounts of nitrate from soil. For most of the samples the TF for NO_2^- could not been calculated because the nitrite contend in soil or vegetable was below the detection limit. The leaves of eggplant and tomatoes proved to have high nitrite absorption potential. As a consequence, the nitrite content must be carefully monitored in the soils on which these vegetables are grown.

3.4. The ions intake rate via vegetables ingestion

3.4.1. The exposure to nitrate and nitrite via vegetables intake

The daily intake for nitrate/nitrite ($DI\_NO_3^-$ /$DI\_NO_2^-$) is presented in Table 4. Generally, $DI\_NO_3^-$ was higher than $DI\_NO_2^-$. The data from the present study indicated that cucumbers, onion, tomatoes and lettuce are higher contributors to nitrate intake than pepper or eggplant.

Table 4. Daily intake of nitrate and nitrite.

Vegetable	Vegetable consumption (g/day/ inhabitant)	$DI\_NO_3^-$ (mg/day)	$DI\_NO_2^-$ (mg/day)
Cucumber	26[(a)]	0.05 – 9.51 (3.46)	ND
Pepper	31[(a)]	0.06 – 0.55 (0.25)	ND
Eggplant	2.3[(b)]	0.001 – 0.016 (0.009)	ND
Tomatoes	105[(a)]	0.05 – 2.78 (1.04)	ND
Onion	28[(b)]	1.84 – 2.73 (2.29)	ND
Lettuce	22[(b)]	0.25 – 4.78 (1.64)	0.04 – 0.38 (0.20)
ADI for an adult with a body weight of 60 kg		*222[(c)]*	*3.6[(c)] / 4.2[(d)]*

[(a)]average daily consumption of vegetables per capita in 2016 based on the data reported by the National Institute of Statistics from Romania (NIS 2017); [(b)]average vegetable consumption of vegetables per capita at European level (WHO 2003); [(c)]acceptable daily intake (ADI) recommended by the European Commission's Scientific Committee on Food (SCF) (EC 1992; EC 1997)*; [(d)]acceptable daily intake (ADI) recommended by the Joint Expert Committee of the Food and Agriculture (JEFCA) of the United Nations/World Health Organization (WHO) (EFSA 2008; FAO/WHO 2003).*

However, the nitrate intake caused by the ingestion of the analysed vegetables represents up to 2.15% from the ADI for nitrate (222 mg of NO_3^- per day for an adult with a body weight of 60 kg), which indicated that the consumption of these vegetables does not represent a risk factor for human health.

The $DI\_NO_2^-$ ranged between 0.04 – 0.38 mg/day (an average of 0.20 mg/day), which corresponds to 0.95 – 9.05% from the $ADI\_NO_2^-$ (4.2 mg of NO_2^- per day for an adult with a body weight of 60 kg), recommended by international forums (FAO/WHO, 2003; EFSA, 2008), indicating that the nitrite content from the lettuce is safe for consumer's health.

3.4.2. The nutritive value of vegetables

The daily intake of minerals via vegetables ingestion and the adequate intakes or the recommended dietary allowances are presented in Table 5.

Potassium was the most abundant individual mineral from the vegetables. The highest potassium intake was found in the tomatoes fruits (47.82 – 190.81 mg/day). Lettuce and onion proved to be another important source of potassium (Table 5). The total potassium intake caused by the ingestion of the analysed vegetables range between 155.17 and 443.28 mg/day, which represents 3.30 – 9.43% from the adequate intake (4,700 mg/day). Potassium plays an important role in human body, having a high contribution in lowering the blood pressure and decreasing the effects of salt (Salunkhe et al., 1991). The scientific literature mentions that potassium-rich vegetables include leafy green vegetables, tomatoes and root vegetables (Vicente et al., 2009).

Another abundant mineral in the analysed vegetables was chlorine, which was found in high level in onion (219.6 – 1,855.0 mg/kg in leaf and 148.2 – 3,610.2 mg/kg in bulb) and in lettuce (0.2 – 676.7 mg/kg) (Table 2). The total DI_Cl^- was between 28.74 and 192.72 mg/day, almost 10% from the adequate intake for a healthy individual which should be between 1,800 and 2,300 mg/day (Table 5).

The ingestion of tomatoes proved to be an important source of calcium (7.09 – 67.56 mg Ca^{2+}/day) and magnesium (2.07 – 14.62 mg Mg^{2+}/day) (Table 5). Calcium is an essential mineral for bone and tooth formation, being also an important mediator of hormonal effects on target organs, and it can be found in high concentration in dark green leafy cabbage family and turnip greens. Magnesium plays an important role in protein synthesis, energy release from muscle, body temperature regulation, proper heart function and bone formation. Generally, the legumes have higher magnesium content than fruits (Vicente et al., 2009).

The results indicate that the onion is an important source of sodium (0.87 – 37.48 mg Na^+/day), this element having an important role in electrolyte balance, adenosine triphosphate coregulating and blood pressure regulation. The international literature mentions that spinach is an important source of sodium (Vicente et al., 2009).

Table 5. Daily intake of minerals via vegetables ingestion.

Vegetable	Cl^- (mg/day)	PO_4^{3-} (mg/day)	Na^+ (mg/day)	K^+ (mg/day)	Mg^{2+} (mg/day)	Ca^{2+}(mg/day)
Cucumber	4.63 – 6.26 (5.48) [(a)]	1.09 – 15.01 (8.48)	0.40 – 1.15 (0.86)	33.73 – 38.51 (36.63)	2.16 – 3.59 (2.81)	2.60 – 10.22 (6.34)
Pepper	2.62 – 7.94 (4.95)	2.31 – 23.87 (13.09)	0.23 – 1.13 (0.53)	12.38 – 55.45 (35.11)	0.95 – 4.58 (2.71)	2.17 – 5.74 (4.45)
Eggplant	0.18 – 0.68 (0.43)	0.18 – 0.90 (0.54)	0.01 – 0.03 (0.02)	0.63 – 4.09 (2.37)	0.04 – 0.21 (0.12)	0.04 – 0.28 (0.16)
Tomatoes	11.40 – 61.88 (33.44)	0.71 – 26.29 (15.19)	1.82 – 5.12 (3.22)	47.82 – 190.81 (123.44)	2.07 – 14.62 (7.76)	7.09 – 67.56 (29.56)
Onion	4.14 – 101.08 (40.83)	11.10	0.87 – 37.48 (15.09)	27.83 – 72.90 (47.73)	0.39 – 7.85 (4.22)	6.57 – 12.97 (8.89)
Lettuce	5.77 – 14.89 (11.12)	0.79 – 12.57 (4.79)	1.86 – 7.69 (5.18)	28.78 – 81.52 (56.17)	0.54 – 6.60 (2.97)	3.86 – 13.81 (8.77)
TOTAL	**28.74 – 192.72**	**16.08 – 89.74**	**5.19 – 52.60**	**155.17 – 443.28**	**6.15 – 37.45**	**22.33 – 110.58**
Recommendation_ Female (>18 years)	***1,800 – 2,300*** [(b)]	***700*** [(d)]	***1,200 – 1,500*** [(b)]	***4,700*** [(b)]	***310 – 320*** [(c)]	***1,000 – 1,300*** [(c)]
Recommendation_ Male (>18 y years)					***400 – 420*** [(c)]	

[(a)]min – maxim (average); [(b)]Adequate Intakes (AI) believed to cover the needs of all healthy individuals in the groups, but lack of data or uncertainty in the data prevent being able to specify with confidence the percentage of individuals covered by this intake (Ross et al., 2011); [(c)] Recommended Dietary Allowances (RDAs), which represents the average daily dietary intake level sufficient to meet the nutrient requirements of nearly all (97–98%) healthy individuals in a group (Ross et al., 2011); [(d)] RDA for phosphorus (Ross et al., 2011);

The ingestion of tomatoes and pepper can be an important source of phosphate (0.71 – 26.29 mg PO_4^{3-}/day and 2.31 – 23.87 mg PO_4^{3-}/day) (Table 5). Inorganic phosphate has a major role in skeletal mineralization and cellular functions (glycolysis, gluconeogenesis, DNA and RNA synthesis, cellular protein phosphorylation, etc.) (DiMeglio et al., 2000).

The data from the present study indicated that the daily intake of the six investigated vegetables provides a mineral intake of Cl^-, PO_4^{3-}, Na^+, K^+, Mg^{2+} and Ca^{2+}, that generally represents 10% of the minerals Adequate Intakes (AI) believed to cover the needs of all healthy individuals in the groups, or the minerals Recommended Dietary Allowances (RDA) sufficient to complete the nutrient requirements of nearly all (97–98%) healthy individuals in a group (Ross et al., 2011).

4. CONCLUSIONS

The present study emphasizes the importance of soil-plant-human pattern for chemical elements transfer into the food chain

The most abundant ions present in soil solution were NO_3^-, Na^+, SO_4^{2-} and K^+. Generally, the ions content slightly decreased from summer to autumn and decreased with soil depth. The average nitrate concentration in soil was relatively constant, with the exception of March 2017, when the content increased because of the fertilizers application.

With the exception of F^-, NO_2^- and NO_3^-, the ions content in the irrigation water was within the limits imposed by national legislation.

The ions content was higher in the leaves than in the fruits of vegetables. The nitrate and nitrite intake caused by the ingestion of the analysed vegetables, represents up to 2.15% and 9.05% from the acceptable daily intake, which indicates that the consumption of these vegetables does not represent a risk factor for human health.

The transfer factor for nitrite was high in the case of eggplant and tomatoes leaf, indicating that they accumulated important amounts of nitrite from soil.

The analysed vegetables contained substantial amounts of minerals, particularly potassium, chlorine and calcium. The daily intake of the six investigated vegetables provides a mineral intake of Cl^-, PO_4^{3-}, Na^+, K^+, Mg^{2+} and Ca^{2+}, which generally represents 10% of the minerals intakes believed to cover the nutrient requirements of a healthy individual.

Performing additional analyses on a much larger number of vegetables species, could improve the results of the present study. These types of studies are important because they are offering to local communities, valuable information regarding the quality of the agricultural soils or the vegetables cultivated, marked or consumed in their areas.

Conflicts of interest

There are no conflicts to declare.

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