POLISH SOCIETY FOR HORTICULTURAL SCIENCE

Folia Hort. 28/2 (2016): 143-150

DOI: 10.1515/fhort-2016-0017

FOLIA HORTICULTURAE

Published by the Polish Society for Horticultural Science since 1989

ORIGINAL ARTICLE | Open access | http://www.foliahort.ogr.ur.krakow.pl

Influence of cultivar on the content of selected minerals in red beet roots (*Beta vulgaris* L.)

***Zofia Nizioł-Łukaszewska*[1]**, *Maria Gawęda*[2]**

[1] Department of Cosmetology
The University of Information Technology and Management in Rzeszow
Kielnarowa 386a, 36-020 Tyczyn, Rzeszów, Poland
[2] Department of Vegetable and Medicinal Plants
University of Agriculture in Krakow
29 Listopada 54, 31-425 Kraków, Poland

ABSTRACT

Beetroot is a vegetable that accumulate heavy metals. This is largely dependent on the cultivar, methods and growing conditions. The aim of the study was to determine the composition of elements in the roots of 15 cultivars of red beet. The analysis assessed the content of macroelements (Na, P) and heavy metals (Cd, Cr, Mn, Zn). Most soils of the Lesser Poland region are exposed to the impact of industrial and transportation pollution. The soils of this region are characterized by strong acidification as well as natural or increased heavy metal content. The experiment was set up at the experimental field of the Department of Vegetable and Medicinal Plants of the University of Agriculture in Krakow, in 2009-2010. On the basis of the performed analysis, 'Opolski' was chosen as the cultivar that was characterized by a high content of macroelements and lower ability to accumulate heavy metals than the other tested cultivars. The lowest ability to accumulate heavy metals (Cd and Cr) was found in the cases of cultivars with cylindrical root shapes, such as Rywal or Opolski. One can indicate such cultivars as Astar F_1 or Nabab F_1 as cultivars recommended for cultivation in ecologically threatened areas.

Key words: accumulation, beet root, heavy metals, macroelements

INTRODUCTION

The total content of mineral components in vegetables varies between 0.5 and 2.5% (Gawęda 1998). Both macro- and microelements have a range of important functions in the human body, and their levels and ratios affect people's health and metabolism of other food components (Śmigielska et al. 2005, Kumar 2015, Wruss et al. 2015). Mineral components present in the body favourably affect the acid-base balance, neutralizing the acidifying effect of consuming fats, carbohydrates and proteins. In addition, mineral components are involved in processes related to the generation of energy, production and regulation of hormone levels and maintenance of immunity (Cieślik 2009). According to research conducted by Kotowska and Wybieralski (1999), health-promoting effects result not only from the consumption of vegetables containing appropriate amounts of macro- and microelements, but also from appropriate ratios among different minerals contained in vegetables. Particular importance is attributed to three ratios: K:Mg, Ca:Mg and K:(Mg + Ca). Based on the study

*Corresponding author.
Tel.: +48 17 866 14 53;
e-mail: zofniz@gmail.com (Z. Nizioł-Łukaszewska).

DE GRUYTER OPEN

by Francke and Klasa (2009), the recommended Ca:Mg ratio is 3. As Majkowska-Gadomska (2010) notes, drawing on the study by Radkowski et al. (2005), the optimum K:Mg ratio is 6, and the K:(Mg + Ca) ratio should be in the range of 1.6-2.2.

Red beets rank among Poland's most popular vegetables with respect to harvest amount. It should, however, be borne in mind that red beets accumulate considerable amounts of heavy metals which may be undesirable (Domagała-Świątkiewicz and Gąstoł 2012). In fact, the degree of accumulation nitrates in red beets is from three to five times higher than in carrots (Biegańska-Marecik et al. 2007). Heavy metals are accumulated in the process of ion uptake from the soil solution via roots and also as a result of dust accumulation on the leaf blades followed by their transport of the heavy metal ions into the plants (Grant et al. 1998). Heavy metals induce a number of processes inside plants. They contribute to a change in the electrical potential of cell membranes or to a change in the pH of the cytoplasm, which ultimately leads to disturbances in plant metabolism (Wójcik and Tukendorf 1995). Plants that accumulate heavy metals are also affected by disorders of water balance (Gawęda 1998). In addition, heavy metals contribute to the generation of peroxide free radicals, which can have an adverse effect on plants (Gambuś 1991, Parashar and Prasad 2013). Heavy metal accumulation capacity depends primarily on the plant species and cultivar, but also on environmental conditions, particularly on the type of soil, grain size distribution, organic matter content, sorption properties and pH (Lorenz et al. 1997). Furthermore, following Sękara and Poniedziałek (1999a,b), a significant correlation has been found between the study location and the content of heavy metals. Red beets cultivated in areas with large amounts of industrial dusts accumulate excessive levels of cadmium, lead and zinc.

The most significant food contaminants on the world – due to their toxicity but also their widespread presence – are the heavy metals cadmium, lead and mercury (Bartodziejska et al. 2010). The toxic effects triggered by these elements can become evident even after a few years of exposure. They contribute to the development of cancer, cardiovascular diseases, kidney disorders and diseases of the nervous system (Zglinicka 2002, Dangour et al. 2009). The Regulation of the Minister of Health in Poland of 13 January 2003 specifies the following maximum permissible levels of heavy metals in vegetables: Cd 0.08 mg kg^{-1} FW, Pb 0.10 mg kg^{-1} FW, Hg 0.02 mg kg^{-1} FW. These tolerances were confirmed by Commission Regulation (EU) of 29 April 2011, which set the maximum levels for Cd and Pb at 0.10 mg kg^{-1} FW.

The aim of the study was to propose red beet cultivars that are characterized by a high content of macronutrients and a low accumulation of heavy metals.

MATERIAL AND METHODS

The experiment was conducted in the experimental field of the Department of Vegetable and Medicinal Plants of the University of Agriculture in Krakow, in 2009-2010. Soil samples were collected for analysis prior to the sowing of red beet with a depth profile of 0-30 cm. The experiment was conducted on typical brown soil. The experimental field featured soil with typical pollution for the Krakow region. The soils of this region are typically characterized by strong acidification as well as natural or increased heavy metal content. On the field of the experiment, the soil has been shown to contain lower levels of heavy metals Cd, Cr and Zn in comparison with other measuring points located in the Krakow region (Report http://www.krakow.pios.gov.pl/publik.php). A study conducted by Koncewicz-Baran and Gondek (2010) in the western part of the Krakow showed a higher content of heavy metals Cd – 1.13 mg kg^{-1}, Cr – 19.8 mg kg^{-1}, Zn – 111 mg kg^{-1} compared to the conducted research (Tab. 1).

15 cultivars of red beet from different breeding companies were evaluated. Among the 15 analysed cultivars, 13 were derived from Polish breeders (Astar F_1, Boro F_1, Ceryl, Chrobry, Czerwona Kula, Egipski, Karmazyn, Nabab F_1, Nochowski, Opolski, Pablo F_1, Patryk, Regulski Cylinder, Okrągły Regulski and Rywal) and two from Dutch ones (Boro F_1, Pablo F_1). These cultivars are

Table 1. Soil analysis from the 0-30 cm layer of the experimental field

Year	NH_4	NO_3	P	K	Ca	Mg	Pb	Cd	Zn	Cr	Ni	pH	Salinity
	(mg dm^{-3})												(g NaCl dm^{-3})
2009	12	73	58	180	906	110	19.8	0.30	11.4	19.8	14.6	6.9	0.27
2010	19	50	67	215	1350	152	17.3	0.32	10.8	21.5	16.4	7.0	0.33

characterized by different root shape, coloration, and yield.

Prior to sowing, the seeds were treated with the fungicide Funaben T (carbendazim, thiuram) from the Chemical Works Organika-Azot SA. The seeds were sown in both years of research on 01.07, using a seed drill. Plants were grown in the third year after organic manure was applied. Based on the results of the soil analysis, additional supplemental fertilization was applied in the spring (nitrate, granular superphosphate, potassium salt). Nutrients were maintained at a level of (mg dm^{-3}) N – 70, P – 60, K – 150 and Ca – 1500. The cultivation of red beet was conducted on low ridges, with sowing in single rows. Thinning was performed in the 2-4 leaf stage, every 8-10 cm on average. There were 25 plants for each 1 m^2 of area. Plots were 6 m^2 of surface area and were arranged in a randomized block design with four replications. In the middle of the vegetative period, the plants were sprayed against *Cercospora beticola* with the fungicide Curzate (copper oxychloride, cymoxanil – Chemical Works Organika-Azot SA) at 20 g of the product per 10 litres of water. The field plots were hand weeded during the vegetation period. The beets were harvested in September in 2009, and in October in 2010. Then the roots that had reached a size adequate for sale were transferred to the laboratory. The roots were washed, cleaned and prepared immediately for further testing. 30 representative roots of each cultivar were taken for laboratory tests and the analysis was performed in triplicate.

The mineral composition of the roots was assessed by the method of atomic absorption proposed by Pinta (1977), which involves the absorption of radiation by elements in the vapour state. In order to transform mineral components into ions, the samples were subjected to dry mineralization. The assay was performed on a Varian Spectr AA-20 (Varian Techtron Pty, Australia).

The obtained results were analysed with Statistica 9.0 software, using the Tukey HSD test at a level of significance of $p < 0.05$. Different letters describe the significantly different values, whereas values with no statistical differences are denoted by the same letter.

RESULTS AND DISCUSSION

The weather conditions in 2009-2010 were quite different. Exceptionally unfavourable weather occurred in 2010, with large amounts of rainfall during the entire growth period – particularly in the last decades (here and in further appearances means 10 successive days) of July and August, when the plot area was temporarily flooded. The highest temperatures were recorded in July in each year. The warmest period was the second week of July in 2010. In contrast, the coldest period was the second decade of October in 2010. The bad weather in 2010 delayed the harvest of roots by around a month (Figs 1 and 2).

In the conducted experiment the content of macronutrients in 15 cultivars of red beet were determined. The content of sodium and phosphorus

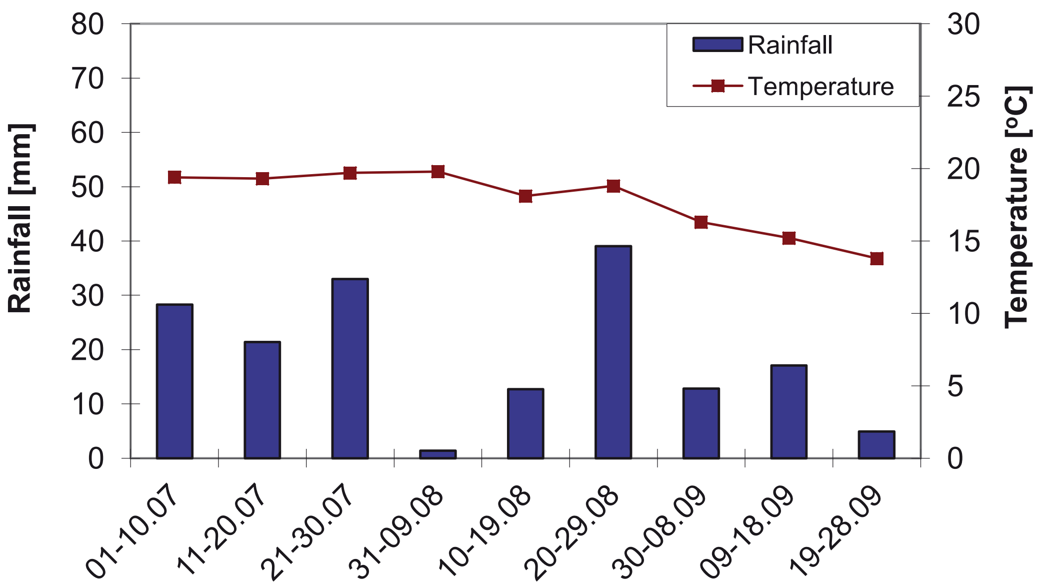

Figure 1. Average temperatures and rainfall sum for 10-day periods in 2009

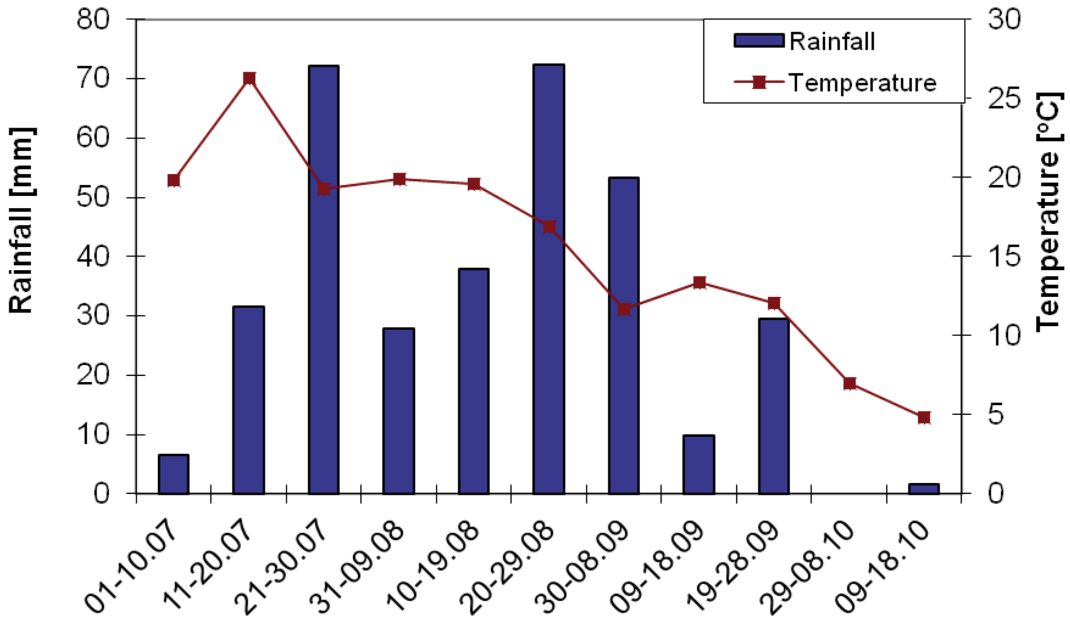

Figure 2. Average temperatures and rainfall sum for 10-day periods in 2010

(based on the average of the years 2009-2010) between cultivars did not differ significantly. The analysis of the macronutrient contents in different years showed that the average content of sodium and potassium for the successive cultivars was lower compared to 2010. Sodium in 2009 ranged from 1.12 mg g^{-1} DW to 6.28 mg g^{-1} DW. In 2010, it ranged from 1.01 mg g^{-1} DW to 4.20 mg g^{-1} DW. Based on the average from 2009, we found that the Opolski cultivar was characterized by the highest content of sodium. It contained about five times as much sodium as the cultivar Nabab F_1, which had least sodium. Also in 2010, the cultivar Opolski was characterized by the highest content of this element. However, this content was not significantly different from other cultivars (Ceryl, Czerwona Kula, Karmazyn, Regulski Cylinder and Rywal).

The content of potassium in 2009 for the successive cultivars ranged from 1.85 mg g^{-1} DW to 4.53 g^{-1} DW. In 2010 it was lower, from 1.84 mg g^{-1} DW to 3.19 mg g^{-1} DW. In 2009, the highest content of potassium was found in cultivar Nochowski. The content of potassium in the roots of 'Nochowski' did not differ significantly from other cultivars (Ceryl, Chrobry, Czerwona Kula, Egipski, Karmazyn, Nochowski, Patryk and Regulski Okrągły). In 2010, the highest content of potassium was found in cultivar Pablo F_1, which was the cultivar included into the group of cultivars with the lowest phosphorus content in 2009. In 2010, an increase in the sodium content by 34% was observed for this cultivar in comparison with 2009 (Tab. 2).

The heavy metal content was determined taking into account zinc and manganese, cadmium and chromium. For zinc and manganese, the same trends as in the case of macronutrients were observed. In 2010, the content of these elements was lower than in the first year of the study. The zinc content in 2009 ranged from 25.78 µg g^{-1} DW to 99.02 µg g^{-1} DW. In 2010 it ranged from 24.25 µg g^{-1} DW to 44.35 µg g^{-1} DW. In 2009, the lowest content of zinc was found in the Boro F_1 cultivar, and the highest in 'Nochowski'. A year later, among the analysed cultivars, 'Nochowski' showed the biggest decline in the zinc content – 60% compared to 2009. In 2010, the lowest content of zinc was also shown in the roots of 'Boro' F_1, as well as in 'Astar' F_1, 'Opolski' and 'Rywal'. The highest was in 'Karmazyn', but it did not differ significantly from the others ('Ceryl', 'Czerwona Kula', 'Karmazyn', 'Nochowski', 'Regulski Cylinder' and 'Regulski Okrągły'). The studies conducted by Sękara et al. (2005) for the Czerwona Kula cultivar of beet showed the Zn content to be 52.1-309 mg kg^{-1} DW. In this study, 'Czerwona Kula' red beet roots had an average of 47.92 µg g^{-1} DW. This result, which was lower compared to the before mentioned study, may be caused by soil or atmospheric conditions.

In 2009, the manganese content was higher than in 2010 and ranged from 12.86 µg g^{-1} DW to 49.51 g^{-1} DW. In 2010 it ranged from 10.71 g^{-1} DW to 27.95 µg g^{-1} DW. In 2009, the lowest content of zinc was observed in 'Boro' F_1, while the highest was in 'Nochowski'. In 2010 the cultivar Regulski Cylinder contained the lowest

Table 2. The content of macroelements (Na, P) in the roots of red beet

Cultivar	Na ($mg\ g^{-1}$ DW)			P ($mg\ g^{-1}$ DW)		
	2009	2010	Mean	2009	2010	Mean
Astar F_1	3.22 c-f*	2.08 a-c	2.65 A	2.88 a-d	2.41 b-e	2.65 A
Boro F_1	1.96 ab	1.17 ab	1.57 A	1.85 a	2.39 b-e	2.12 A
Ceryl	4.20 f	3.15 b-d	3.68 A	3.96 d-f	2.64 c-e	3.30 A
Chrobry	2.12 a-c	2.07 a-c	2.10 A	4.02 d-f	2.26 bc	3.14 A
Czerwona Kula	4.19 f	3.00 b-d	3.60 A	3.81 d-f	2.43 c-e	3.12 A
Egipski	3.62 d-f	1.97 a-c	2.80 A	3.40 c-f	2.28 b-d	2.84 A
Karmazyn	3.16 c-f	3.15 b-d	3.16 A	4.20 ef	2.67 de	3.44 A
Nabab F_1	1.12 a	1.01 a	1.07 A	3.26 b-e	2.30 b-d	2.78 A
Nochowski	3.98 ef	2.71 a-d	3.35 A	4.53 f	2.59 c-e	3.56 A
Opolski	6.28 g	4.20 d	5.24 A	3.12 b-e	2.59 c-e	2.86 A
Pablo F_1	2.06 a-c	1.27 ab	1.67 A	2.10 a	3.19 f	2.65 A
Patryk	2.95 b-d	1.98 a-c	2.47 A	3.38 c-f	1.84 a	2.61 A
Regulski Cylinder	2.93 b-e	3.86 cd	3.40 A	2.22 a-c	2.56 c-e	2.39 A
Regulski Okrągły	2.73 b-d	1.96 a-c	2.35 A	4.21 ef	2.72 e	3.47 A
Rywal	2.05 a-c	4.14 d	3.10 A	2.21 a-c	2.04 ab	2.13 A
Mean	3.10	2.51	2.81	3.28	2.46	2.87

*Values within columns marked with the same letter do not differ significantly at $p < 0.05$ according to Tukey's HSD test

content of manganese, however, it did not differ significantly from 'Egipski' and 'Karmazyn'. The richest in manganese were roots of 'Regulski Okrągły', 'Astar' F_1, 'Boro' F_1, 'Ceryl', 'Chrobry', 'Czerwona Kula', 'Nabab' F_1 and 'Nochowski' (Tab. 3). Tymińska-Zawora and Kochańska (1982) reported that red beets exhibit a particular tendency for the accumulation of manganese. Other factors contributing to the high content of manganese in the roots include low pH and high soil humidity, as they trigger a reduction of divalent forms, which are the easiest to be transported and absorbed within the plant (Dubiel 1978). The effect of significant Mn accumulation was not observed in this research, which can be explained by neutral soil pH. According to Sękara and Poniedziałek (1999b), the

Table 3. The content of heavy metals (Mn, Zn) in the roots of red beet

Cultivar	Mn ($\mu g\ g^{-1}$ DW)			Zn ($\mu g\ g^{-1}$ DW)		
	2009	2010	Mean	2009	2010	Mean
Astar F_1	21.63 b*	23.67 de	22.65 A	35.94 c	24.25 a	30.10 A
Boro F_1	12.86 a	21.67 de	17.27 A	25.78 a	26.00 a	25.89 A
Ceryl	42.55 h	22.30 de	32.43 A	84.75 i	42.90 ef	63.83 AB
Chrobry	40.30 g	24.90 de	32.60 A	72.87 h	37.05 c-e	54.96 AB
Czerwona Kula	29.39 de	25.35 de	27.37 A	57.14 e	38.70 c-f	47.92 AB
Egipski	34.13 f	14.45 a-c	24.29 A	61.52 f	34.55 b-d	48.04 AB
Karmazyn	39.34 g	13.87 ab	26.61 A	58.23 ef	44.35 f	51.29 AB
Nabab F_1	28.59 d	21.45 de	25.02 A	55.90 e	35.30 b-d	45.60 AB
Nochowski	49.51 i	20.60 b-d	35.06 A	99.02 j	40.15 d-f	69.59 B
Opolski	31.16 e	20.97 cd	26.07 A	60.85 f	29.65 ab	45.25 AB
Pablo F_1	22.32 b	20.40 b-d	21.36 A	40.31 d	34.45 b-d	37.38 AB
Patryk	30.46 de	19.47 b-d	24.97 A	43.30 d	33.30 bc	38.30 AB
Regulski Cylinder	20.71 b	10.71 a	15.71 A	36.92 c	41.65 ef	39.29 AB
Regulski Okrągły	38.99 g	27.95 e	33.47 A	66.69 g	38.65 c-f	52.67 AB
Rywal	25.03 c	19.00 b-d	22.02 A	31.78 b	26.60 a	29.19 A
Mean	31.13	20.45	25.79	55.40	35.17	45.29

*Explanations: see Table 2

Table 4. The content of heavy metals (Cd, Cr) in the roots of red beet

Cultivar	Cd (μg g^{-1} DW)			Cr (μg g^{-1} DW)		
	2009	2010	Mean	2009	2010	Mean
Astar F_1	0.33 ab*	0.67 ab	0.50 A	1.27 a-c	2.62 ab	1.95 A
Boro F_1	0.37 ab	0.74 a-c	0.56 A	0.59 a	2.81 bc	1.70 A
Ceryl	0.94 e	0.70 a-c	0.82 A	2.07 c-e	3.86 e	2.97 A
Chrobry	0.72 de	0.84 cd	0.78 A	2.17 c-e	3.06 b-d	2.62 A
Czerwona Kula	0.56 b-d	0.83 cd	0.70 A	1.50 a-d	2.92 bc	2.21 A
Egipski	0.67 cd	0.91 d	0.79 A	2.36 de	3.33 c-e	2.85 A
Karmazyn	0.53 a-d	0.94 d	0.74 A	1.44 a-d	2.99 bc	2.22 A
Nabab F_1	0.36 ab	0.64 ab	0.50 A	1.28 a-c	2.72 ab	2.00 A
Nochowski	0.70 de	0.64 ab	0.67 A	2.18 c-e	3.72 e	2.95 A
Opolski	0.47 a-d	0.59 a	0.53 A	1.23 a-c	2.17 a	1.70 A
Pablo F_1	0.36 ab	0.92 d	0.64 A	2.36 de	3.09 b-d	2.73 A
Patryk	0.44 a-c	0.91 d	0.68 A	1.81 c-e	2.83 bc	2.32 A
Regulski Cylinder	0.30 a	0.79 b-d	0.55 A	2.80 e	3.60 de	3.20 A
Regulski Okrągły	0.53 a-d	0.59 a	0.56 A	1.64 b-d	2.67 ab	2.16 A
Rywal	0.47 a-d	0.66 ab	0.57 A	0.80 ab	2.23 a	1.52 A
Mean	0.52	0.76	0.64	1.70	2.97	2.34

*Explanations: see Table 2

content of manganese in red beet roots (‘Czerwona Kula’) was between 37.4 and 71.6 mg kg^{-1} DW. This range clearly demonstrates a variability in the accumulation of the metal depending on the cultivation conditions. Studies by Szopińska and Gawęda (2013) showed that weather conditions had an impact on the content of copper, zinc, potassium, magnesium and calcium in the roots of cultivated beets. As Mercik (2002) noted, excessive rainfall may contribute to the leaching of minerals or their displacement with the solid phase of the soil. In the present experiment, the levels of macroelements were also found to be lower in the second year of the study, which may have coincided with a very high amount of rainfall throughout the entire vegetative period. The conducted research also allowed us to specify the content of macroelements (Ca, K, Mg), microelements (Cu, Fe) and heavy metals (Ni, Pb) in soil with pollution typical for the Krakow region (Nizioł-Łukaszewska and Gawęda 2015).

Previous research has shown that the content of mineral components identified in the roots of beets cultivated using organic or conventional methods can be significantly influenced by the method of cultivation (Domagała-Świątkiewicz and Gąstoł 2013). The content of phosphorus in organically grown beet roots was demonstrated to be significantly higher (Szopińska and Gawęda 2013). Different conclusions were reached in the study by Mader et al. (1993). The researchers failed to show any differences in the level of phosphorus in the roots cultivated by conventional, organic and integrated methods.

In the case of cadmium and chromium, the opposite trend as compared to the other elements was observed. The research showed that the content of these elements in the roots of beet in 2009 was lower than in 2010. It also showed that cultivars with a cylindrical root shape such as ‘Rywal’ and ‘Opolski’ cumulated heavy metals in the lowest degree. In 2009, the lowest content was also demonstrated for a cultivar with a cylindrical shaped root – Regulski Cylinder (0.30 μg g^{-1} DW). However, this cultivar was not significantly different from the other 10 analysed cultivars. The highest content of cadmium was shown for the cultivar Ceryl – 0.94 μg g^{-1} DW – which did not differ significantly from ‘Chrobry’ and ‘Nochowski’. In 2010 the cadmium content ranged from 0.59 μg g^{-1} DW (‘Opolski’ and ‘Regulski Okrągły’) to 0.94 μg g^{-1} DW (‘Karmazyn’).

The chromium content in the analysed beet roots in 2009 ranged from 0.59 μg g^{-1} DW (‘Boro’ F_1) to 2.80 μg g^{-1} DW (‘Regulski Cylinder’). In 2010, the chromium content was higher and ranged from 2.17 μg g^{-1} DW (‘Opolski’) to 3.86 μg g^{-1} DW (‘Ceryl’) (Tab. 4).

According to Grembecka et al. (2008), the level of chromium in the roots of red beets was 0.004 -0.005 mg 100g g^{-1} DW. For nickel, the value was

0.003-0.004 mg 100 g^{-1} DW. In contrast, Kabata-Pendias and Pendias (1999) claim the content of Cr in garden vegetables to be in the range of 0.02 -0.15 mg kg^{-1} DW. The differences between test results may be caused by such factors as weather conditions, soil and cultivar. featured

Under the Commission Regulation (EU) of 29 April 2011, more rigorous requirements were adopted for the maximum levels of heavy metals, amounting to 0.10 mg kg^{-1} DW for Cd. Converted to the dry weight of beets, the mean maximum level of Cd is 0.67 mg kg^{-1} DW. For cadmium, the maximum permissible levels were exceeded in six of the cultivars investigated in the study (Ceryl, Chrobry, Czerwona Kula, Egipski, Karmazyn and Patryk).

CONCLUSIONS

1. Based on the survey performed in 2009, the authors demonstrated a lower average content of Na, P, Mn and Zn compared to 2010. In the case of Cd and Cr, an inverse trend was observed.
2. The Opolski cultivar was chosen as the one that was characterized by a high content of macroelements and lower ability to accumulate heavy metals than the other cultivars tested.
3. Cultivars with cylindrical shaped roots such as Rywal or Opolski cumulated the least heavy metals (Cd and Cr). Such cultivars as Astar F_1, Nabab F_1 can also be recommended for ecologically threatened areas.
4. For cadmium, the maximum permissible levels were exceeded in six of the cultivars investigated in the study (Ceryl, Chrobry, Czerwona Kula, Egipski, Karmazyn and Patryk).

FUNDING

Scholarships for members of full-time and part-time PhD studies as part of the project titled "Podkarpacki fundusz stypendialny dla doktorantów" introduced by the Human Capital Operational Program.

AUTHOR CONTRIBUTIONS

M.G. – designed the experiments; Z.N.-Ł. – performed analytical measurements and performed statistical analyses; Z.N.-Ł. and M.G. – contributed to manuscript writing.

CONFLICT OF INTEREST

Authors declare no conflict of interest.

REFERENCES

Bartodziejska B., Gajewska M., Czajkowska A., 2010. Research on content of heavy metals contamination in independent agrarian production using atomic absorbtion spectrometry technique. ENVIRON 43: 38-44.

Biegańska-Marecik R., Czapski J., Błaszczyk P., 2007. Określenie wpływu odmiany i procesu technologicznego na występowanie smaku gorzkiego w buraku ćwikłowym [Determination of cultivar and technological process effect on the occurrence of bitter taste in red beet]. Żywn. Nauk. Technol. Ja. 3(52): 62-70.

Cieślik E., 2009. Prozdrowotne właściwości warzyw [Healthy properties of the vegatables]. Zesz. Probl. Post. Nauk Roln. 539: 87-97.

Commission Regulation (EU) No 420/2011 of 29 April, 2011 amending Regulation (EC) No 1881/2006 setting maximum levels for certain contaminants in foodstuffs.

Dangour A., Dodhia S.K., Hayter A., Allen E., Lock K., Uauy R., 2009. Nutritional quality of organic foods: a systematic review. Am. J. Clin. Nutr. 90: 680-685.

Domagała-Świątkiewicz I., Gąstoł M., 2012. Comparative study on mineral content of organic and conventional carrot, celery and red beet juices. Acta Sci. Pol., Hortorum Cultus 11(2): 173-183.

Domagała-Świątkiewicz I., Gąstoł M., 2013. Soil chemical properties under organic and conventional management systems in south Poland. Biol. Agric. Hort. 29(1): 12-28.

Dubiel W., 1978. Zawartość przyswajalnych form B, Mn, Cu i Mo w zależności od ilości części spławialnych i materii organicznej oraz odczynu gleb południowo-wschodniej Polski [The content of available forms of B, Mn, Cu, Mo, depending on organic matter and soil pH south-eastern Polish]. Zesz. Nauk. AR w Krakowie 147.

Francke A., Klasa A., 2009. The effect of cultivation method on the macronutrients content of shallot bulbs (*Allium ascolonicum* L.). Veg. Crops Res. Bull. 70: 163-170.

Gambuś F., 1991. Porównanie pobierania metali ciężkich przez warzywa przy zróżnicowanej ich zawartości w glebie [Comparison of the uptake of heavy metals by vegetable crops with a differentiated soil content of the former]. Biul. Region ZUP AR w Krakowie 295: 41-49.

Gawęda M., 1998. Rola niektórych składników podłoża w ograniczaniu kumulacji ołowiu przez wybrane gatunki warzyw korzeniowych i liściowych oraz ich znaczenie dla zachowania wartości biologicznej roślin [The role of some components of the substrate in reducing the accumulation of lead by selected species of root vegetables and leafy and their importance for preserving biological value of plants]. Zesz. Nauk. AR w Krakowie 240.

GRANT C.A., BUCKLEY W.T., BAILEY L.D., SELLES F., 1998. Cadmium accumulation in crops. Can. J. Plant Sci. 78: 1-17.

GREMBECKA M., SZEFER P., GURZYŃSKA A., DYBEK K., 2008. Ocena jakości zdrowotnej wybranych warzyw na podstawie ich składu pierwiastkowego [Evaluation of the prohealth quality of selected vegetables based on the elemental composition]. Bromat. Chem. Toksykol. 3: 328-332.

KABATA-PENDIAS A., PENDIAS H., 1999. Biogeochemia pierwiastków śladowych. PWN, Warszawa, Poland.

KOTOWSKA J., WYBIERALSKI J., 1999. Kształtowanie się stosunków ilościowych K, Ca i Mg w glebie oraz roślinnach [Formation of quantitative ratios between K, Ca and Mg in soil and in plants]. Biul. Magnezol. 4(1): 104-110.

KONCEWICZ-BARAN M., GONDEK K., 2010. Zawartość pierwiastków śladowych w glebach użytkowanych rolniczo [Content of trace elements in agricultural soils]. Infrastructure and Ecology of Rural Areas 14: 65-74.

KUMAR Y., 2015. Beetroot: A Super Food. IJESTA 1(3): 20-26.

LORENZ S.E., HAMON R.E., HOLM P.E., DOMINQUES H.C., SEQUEIRA E.M., CHRISTENSEN T.H., et al., 1997. Cadmium and zinc in plants and soil solutions from contaminated soils. Plant Soil 189: 21-31.

MADER L., PFIFFNER L., NIGGLI U., 1993. Effect of three farming systems (bio-dynamic, bio-organic, conventional) on yield quality of beetroot (*Beta vulgaris* L. var. *esculenta* L.) in a seven year crop rotation. Acta Hortic. 339: 11-31.

MAJKOWSKA-GADOMSKA J., 2010. Badania nad oddziaływaniem bezpośredniego osłaniania roślin i ściółkowania gleby na wzrost, rozwój oraz plonowanie melona (*Cucumis melo* L.). Rozpr. Nauk. Monogr., UWM w Olsztynie 159.

MERCIK S., 2002. Chemia rolna. Podstawy teoretyczne i praktyczne [Basic theoretical and practical aspects of agricultural chemistry]. SGGW, Warszawa, Poland.

NIZIOŁ-ŁUKASZEWSKA Z., GAWĘDA M., 2015. Porównanie składu pierwiastkowego korzeni buraka ćwikłowego (*Beta vulgaris* L.) w zależności od odmiany [Comparison of the elemental composition of red beet (*Beta vulgaris* L.) roots depending on the cultivar]. Fragm. Agron. 32(2): 79-86.

PARASHAR P., PRASAD F.M., 2013. Study of heavy metal accumulation in sewage irrigated vegetables in different regions of Agra District, India. OJSS 3: 1-8.

PINTA M., 1977. Absorpcyjna spektrometria atomowa – zastosowanie w analizie chemicznej. PWN, Warszawa, Poland.

RADKOWSKI A., GRYGIERZEC B., SOŁEK-PODWIKA K., 2005. Zawartość składników mineralnych w wybranych gatunkach i odmianach traw [Content of mineral components in some species and varieties of grass]. J. Elementol. 10(1): 121-128.

Regulation of the Minister of Health of 13 January, 2003 on the maximum levels of chemical and biological contaminants that may be present in food, food ingredients, allowed additional substances, substances that help in the processing or on food. Journal of Laws No. 37, item 325.

Report http://www.krakow.pios.gov.pl/publik.php; cited on 17 Jun 2013.

SĘKARA A., PONIEDZIAŁEK M., 1999a. Akumulacja metali ciężkich przez wybrane warzywa korzeniowe uprawiane wokół aglomeracji krakowskiej. Część I. Kadm, miedź, ołów i cynk [Accumulation of heavy metals by some species of root vegetables grown around Cracow urban agglomeration. Part I. Cadmium, copper, lead and zinc]. Zesz . Probl. Post. Nauk Rol. 466: 397-411.

SĘKARA A., PONIEDZIAŁEK M., 1999b. Akumulacja metali ciężkich przez wybrane warzywa korzeniowe uprawiane wokół aglomeracji krakowskiej. Część II. Chrom, żelazo, mangan i nikiel [Accumulation of heavy metals by some species of root vegetables grown around Cracow urban agglomeration. Part II. Chromium, iron, manganese and nickel]. Zesz. Prob. Post. Nauk Rol. 466: 413-428.

SĘKARA A., PONIEDZIAŁEK M., CIURA J., JĘDRSZCZYK E., 2005. Zinc and copper accumulation and distribution in the tissues of nine crops: implications for phytoremediation. Pol. J. Environ. Stud. 14(6): 829-835.

SZOPIŃSKA A., GAWĘDA M., 2013. Comparison of yield and quality of red beet roots cultivated using conventional, integrated and organic method. J. Hort. Res. 21(1): 107-114.

ŚMIGIELSKA H., LEWANDOWICZ G., GAWĘCKI J., 2005. Przyswajalność składników mineralnych. Biopierwiastki w żywności [Bioavailability of minerals. Bioelements in food]. Przem. Spoż. 7: 28-32.

TYMIŃSKA-ZAWORA K., KOCHAŃSKA W., 1982. Wstępne wyniki badań składu chemicznego niektórych warzyw korzeniowych w warunkach emisji pyłów z Kombinatu HiL. Zesz. Nauk. AGH. Sozologia i Sozotechnika 17: 71-92.

WÓJCIK A., TUKENDORF A., 1995. Strategia unikania stresu w odporności roślin na metale ciężkie [Stress avoidance strategy in heavy metal resistance of plants]. Wiad. Bot. 39(3/4): 33-40.

WRUSS J., WALDENBERGER G., HUEMER S., UYGUN P., LANZERSTORFER P., MULLER U., et al., 2015. Compositional characteristics of commercial beetroot products and beetroot juice prepared from seven beetroot cultivars grown in Upper Austria. J. Food Compost. Anal. 42: 46-55.

ZGLINICKA A., 2002. Toksyczność kadmu i ołowiu. Aura 2: 30-31.

Received April 1, 2016; accepted July 13, 2016