QUANTITATIVE RELATIONS BETWEEN THE CONTENT OF SELECTED TRACE ELEMENTS IN SOIL EXTRACTED WITH 0.03 M CH$_3$COOH OR 1 M HCL AND ITS TOTAL CONCENTRATION IN CARROT STORAGE ROOTS

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Abstract. There is an existing need for the development of rapid and easy-to-perform methods for analyzing chemical composition of soil basing on simultaneous extraction of many elements in a single solution. Furthermore, it is desirable that mineral concentration determined in soil using these methods should be significantly correlated with its content in plants. Many researches indicated that soil concentration of heavy metals and trace elements after extraction using 0.01 M CaCl$_2$ did not reflect its content in vegetable plants.. The aim of the research was to determine the relation between soil content of: Al, B, Ba, Cd, Co, Cr, Cu, Fe, Li, Mn, Mo, Ni, Pb, Sr, Ti, V and Zn extracted in 0.03 M CH$_3$COOH as well as 1 M HCl and its content in carrot storage roots. In 2008–2009 studies were carried out on soil samples after carrot cultivation (from 0–30 cm, 30–60 cm and 60–90 cm layers) as well as on carrot storage roots grown on the same soil site. In total, analysis of chemical composition (with respect to the content of tested elements) comprised: 112 samples of carrot storage roots, 112 soil samples from 0–30 cm layer as well as 48 soil samples from 30–60 cm and 60–90 cm layers. Higher applicability of soil extraction with 0.03 M CH$_3$COOH (commonly used for macro element chlorides and boron determination) in comparison to extraction with 1 M HCl was demonstrated in reference to the estimation of the relation between soil and carrot content of: Al, B, Ba, Cd, Cr, Cu, Li, Ni, Sr, Ti and Zn. Application of 1 M HCl gave relatively better results when compared to the extraction with 0.03 M CH$_3$COOH with respect to calculated values of correlation coefficient for Co, Fe, Mn, Mo and Pb content in soil and carrot. Content of Co, Mo, Pb and V in soil after extraction using 0.03 M CH$_3$COOH was below the limits of its detection using ICP-OES spectrometer. No relation was found between vanadium content in soil (analyzed after extraction with 1 M HCl) and its content in carrot storage roots.

Key words: 0.03 M acetic acid, 1 M hydrochloric acid, trace elements, carrot

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INTRODUCTION

In the past years in many countries several dozen soil extraction methods have been developed to enable determination of numerous elements in a single soil extract [Nowosielski 1974, Komosa 2000]. The following ones can be included to the most common extraction methods for soils and substrates: extraction with 0.03 M CH_3COOH – the universal method, application of solution containing: $EDTAH_4$, NH_3, $C_3H_8O_7H_2O$ and $(CH_3COO)_2Ca \cdot 2H_2O$ – the Lindsay method [Nowosielski 1974], usage of 1 M HCl-Rinkis method [Gorlach et al. 1999], 0.01 M $CaCl_2$ [Houba et al. 1997], extraction with water for peat substrates and mixture of $CaCl_2$ with DTPA [Nowak and Strojny 2004, Strojny and Nowak 2004].

For chemical analysis of soil and substrates for horticultural production (excluding pomology), the universal method (for macroelements and boron determination) as well as Lindsay method (for Fe, Mn, Zn, Cu and Mo) are commonly used in Poland [Nowosielski 1974]. On the other hand, extraction with 1 M HCl [Gorlach et al. 1999] is applied for estimation of microelement content in agricultural soils, being more convenient in respect of medium preparation and soil extract storage in comparison to Lindsay method.

Studies conducted by Tyksiński [1985] revealed differentiated extraction capacity of Lindsay solution with regard to Mo, Cu, Fe, Mn and Zn as it varied from 32% (for Mo) to 96% (for Mn). Sady et al. [1998] confirmed that simple and fast extraction with 0.01 M $CaCl_2$ was useful for determination in a single solution of easily available forms of Cd, Cu, Mn and Zn (also Fe to a lesser extent) in soils of different physicochemical properties. However, further research indicated that changes in Cd, Cu and Zn accumulation in carrot storage roots (under the influence of diverse nitrogen fertilization and foliar nutrition) had no relation with differentiated content of these elements in soil after extraction with 0.01 M $CaCl_2$ [Smoleń and Sady 2006, 2007a, b, 2008]. In study carried out by Smoleń and Sady [2009] applied forms of nitrogen fertilization significantly influenced level of readily soluble (in 0.01 M $CaCl_2$) forms of B, Be, Bi, K, Li, Mg, Mn, Mo, Na, Ni and Sr in soil after carrot cultivation but observed changes correlated with plant accumulation only in respect of Mn and Sr. Therefore, there is a need to search for efficient, fast and simple methods of micronutrient and trace element determination in soil that would reflect its content in plant tissues. Komosa and Safecka [2002] informed that in fertilization requirement diagnostics there is a tendency to apply solution with weaker extraction force but better correlating with the level of nutrient uptake by plants.

The aim of the research was to found a dependency between soil content of: Al, B, Ba, Cd, Co, Cr, Cu, Fe, Li, Mn, Mo, Ni, Pb, Sr, Ti, V and Zn extracted using 0.03 M CH_3COOH or 1 M HCl and its content in carrot storage roots.

MATERIAL AND METHODS

The study was conducted in 2008–2009 in Experimental Station of Agricultural University in Kraków located in Mydlniki district of Kraków (E 19° 50' 47,2''; N 50° 04' 43,9'', 227 m.a.s.l.). Carrot 'Kazan F_1' was grown on 30 cm high raised beds with

67.5 cm space between rows. Cultivation was carried out on heavy soil classified as fen soil characterized by comparable granulometric composition and relatively: high content of organic matter, even soil reaction about pH 7.0 as well as low total salt concentration (EC) in 0–30 cm, 30–60 cm and 60–90 cm layers (tab. 1). Prior to seed sowing NPK fertilization was applied on the basis of chemical analysis of soil supplementing nutrient content to optimal level for carrot cultivation [Sady 2006]. In both years of the study, seed sowing was carried out at the end of April (in a seedling rate of 700 thousand seeds per 1 hectare) while carrot harvest at the end of September.

Table 1. Physicochemical properties of soil before carrot cultivation in 2008–2009
Tabela 1. Fizykochemiczne właściwości gleby przed uprawą marchwi w latach 2008–2009

Soil layers Warstwa gleby cm	Soil texture class Grupa granulo-metryczna	Content of soil fractions Zawartość części ziemistych w glebie			Content of organic matter Zawartość materii organicznej		pH_{H2O}		EC mS·cm^{-1}	
		sand piasek %	silt – pył %	clay –ił %	2008	2009	2008	2009	2008	2009
0–30		14	45	41	2.84	3.41	6.98	7.10	0.26	0.11
30–60	silty clay pył ilasty	14	42	44	1.81	3.10	7.15	7.01	0.16	0.11
60–90		11	41	48	1.53	2.52	7.23	7.00	0.18	0.15

The research comprised samples of carrot storage roots and soil after carrot cultivation from field experiments conducted in the Experimental Station. In 2008, total area under carrot cultivation amounted to 756 m^2 (56 replicates – plots of 2.7 m × 5 m) while in 2009 – 14 000 m^2 (94 plots of 2.7 m × 5 m and 20 plots of 5 m × 5.4 m).

The content of: Al, B, Ba, Cd, Co, Cr, Cu, Fe, Li, Mn, Mo, Ni, Pb, Sr, Ti, V and Zn in carrot and soil samples was determined by ICP-OES method using high resolution Prodigy Teledyne Leeman Labs spectrometer. The spectrometer was calibrated using Merck's ICP multi-element standard no. VI and no. XVI. Content of tested elements in soil was assayed after sample preparation using two methods. Extraction with 0.03 M CH$_3$COOH was applied for soil samples at its natural humidity [the universal method – Nowosielski 1974]. For air-dried, 1 mm – sieved soil samples extraction with 1 M HCl was used – Rinkis method [Gorlach et al 1999]. The accumulation of tested elements in carrot samples was determined after mineralization in 65% super pure HNO$_3$ (Merck no. 100443.2500) using a CEM MARS-5 Xpress microwave oven [Pasławski and Migaszewski 2006].

In total, analysis of chemical composition included: 112 samples of carrot storage roots (each of ca. 5 kg) and soil from 0–30 cm layer as well as 48 samples of soil separately from 30–60 cm and 60–90 cm layer. Diverse climatic conditions in both years of the study had an insignificant influence on mineral composition of plants and soil after carrot cultivation. The analyzed number of samples allowed to obtain normal distribution for the content of the majority of tested elements in soil and carrot samples – detailed data not presented.

Obtained results were statistically verified by Statistica 8.0 PL programme for significance level P < 0.05. Correlation coefficients were calculated for concentration of tested elements in soil (after extraction with 0.03 M CH_3COOH and 1 M HCl – *x* variable) and its content in carrot storage roots – *y* variable (tab. 2 and 3).

RESULTS AND DISCUSSION

Content of tested elements in soil versus its concentration in carrot roots. Type of extraction solution influences the level of determined content of mineral elements in soil. Application of sequential extraction procedures allows to assay speciation forms of trace elements and micronutrients characterized by different solubility level and availability for plants [Chłopecka 1994, Quevauviller et al. 1994]. Research conducted by Davies [1992] revealed a significant dependency between Cd, Pb and Zn content in radish roots and leaves and its concentration in soil after extraction with 0.05 M EDTA and 1 M NH_4NO_3 (easily soluble fraction) as well as concentrated HNO_3. On the other hand, McLaughlin et al. [1997] found no relation in respect of Cd content in soil (extracted for 7 days in 0.05 M EDTA) and potato tubers.

The usefulness of 0.03 M CH_3COOH extraction solution for determination of Al, As, Ba, Cd, Cu, Fe, Li, Mn, Ni, Pb, Sr and Zn content in soil was previously described [Smoleń 2009]. In mentioned study changes in B, Mn, Li, Ti and Sr accumulation in carrot reflected soil content of these elements after extraction using 0.03 M CH_3COOH or 1 M HCl.

In the present research a statistically significant positive correlation was found between the level of: Al, B, Ba, Cd, Cu, Sr and Zn in three layers of soil (0–30 cm, 30–60 cm and 60–90 cm) analyzed in 0.03 M CH_3COOH and its content in carrot roots (tab. 2 and 3). Accumulation of Al, B, Cu, Sr and Zn in roots was related at the highest rate with its content in 30–60 cm layer of soil – value of correlation coefficients for Al, B, Cu, Sr, Zn were equal to r = 0.77, 0.94, 0.86, 0.94, 0.53, respectively. Comparable values of correlation coefficients for B and Sr were calculated for 60–90 cm layer (r = 0.92 and 0.94, respectively). The highest correlation coefficient value for Ba and Cd was found in relation to 0–30 cm layer.

In reference to Al, Ba, Ba, Cd, Cu, Sr and Zn, content of these elements in carrot roots was correlated in higher extent with its soil content (in layers: 0–30 cm, 30–60 cm and 60–90 cm) analyzed in 0.03 M CH_3COOH rather than 1 M HCl. In the case of Cd this relation was found only in respect of 0–30 cm soil layer while for Zn – in reference to layers: 0–30 cm and 60–90 cm. In studies carried out by Sękara and Poniedziałek [1999] among tested Cd, Cu, Pb and Zn in soil (layers: 0–20 cm, 20–40 cm, 40–80 cm), significant correlation between content of these elements in soil and carrot was found in case of: Pb in 0–20 cm layer (r = 0.66), Cu in 20–40 cm layer (r = 0.69). Still, authors did not presented the method of soil sample preparation (extraction or mineralization) due to analysis.

In current research, content of Al, B, Ba, Cd, Cu, Sr and Zn assayed in individual soil layers (0–30 cm, 30–60 cm and 60–90 cm) after 1 M HCl extraction was not that unambiguously correlated with its accumulation in carrot as it was revealed in respect of

0.03 M CH₃COOH extraction method (tab. 2 and 3). Correlation coefficient values for Al, Ba, Ba, Cd, Cu, Sr and Zn level in soil (analyzed in 1 M HCl) and its content in carrot were diversified for particular elements and statistically significant only in selected cases. For soil layers: 0–30 cm, 30–60 cm and 60–90, correlation coefficients for individual elements were respectively equal to: Al (–, n, –), B (–, –, –), Ba (+, n, –), Cd (n, +, +), Cu (–, n, –), Sr (n, n, –) and Zn (n, –, –); where: „+" means positive value, „–" negative value and „n" no statistical significance of correlation coefficient.

In the case of Cr, Li and Ni determined in soil after 0.03 M CH₃COOH extraction, content of these elements in carrot was significantly positively correlated with its content in 30–60 cm, 60–90 cm soil layers (tab. 2 and 3). In these both layers accumulation of Cr, Li and Ni in carrot was correlated to greater extent with its content in soil after extraction with 0.03 M CH₃COOH rather than 1 M HCl. Cr and Li concentration in 0–30 cm soil layer analyzed in 1 M HCl was in a significant way but relatively weakly correlated with its accumulation in carrot. That dependency was not found for Ni determined in the same extraction medium in 0–30 cm soil layer. Statistically significant negative correlation ($r = -0.31$) between Ti level in soil and carrot was calculated only in reference to extraction in 0.03 M CH₃COOH of soil samples from 0–30 cm layer (tab. 3).

A significantly higher relation was found between Al, B, Ba, Cd, Cr, Cu, Li, Ni, Sr, Ti and Zn content in soil and carrot roots after extraction using the 0.03 M CH₃COOH than 1 M HCl. A possible explanation could be that 0.03 M CH₃COOH is a much more gentle extractor than 1 M HCl. Results of mineral element determination in soil after strong extraction usually weakly correlate with the level of its uptake by plants [Westerman 1990].

In respect of manganese, a statistically significant correlation was found between Mn content in 0–30 cm layer (extracted using 0,03 M CH₃COOH) as well as 30–60 cm and 60–90 cm layer of soil (in 1 M HCl) and its content in carrot roots (tab. 3).

Relation of statistical significance between Fe level in soil and plant was revealed only for its determination in 30–60 cm and 60–90 cm layers of soil after extraction by 1 M HCl (tab. 3). In this case a relatively high reaction (pH) of soil could have affected obtained results (tab. 1). Lindsey and Schwab [1982] informed that iron solubility decreases approximately 1000 times with increasing soil reaction of one pH unit. This finding was later confirmed by Tyler and Olsson [2001].

Analysis of soil and plant chemical composition revealed that Co and Pb accumulation in carrot roots was negatively correlated ($r = -0.39$ and -0.47, respectively) with its content in 30–60 cm layer of soil extracted by 1 M HCl (tab. 2 and 3). In the case of Mo determination, the content of this element in carrot was negatively correlated with its level in all three layers of soil (0–30 cm, 30–60 cm, 60–90 cm) after using the same extraction medium. No relation was found between vanadium content in soil extracted with 1 M HCl and its accumulation in storage roots of carrot. It should be emphasized that Co, Mo, Pb and V level in soil after extraction using 0.03 M CH₃COOH was below the limits of detection of ICP-OES spectrometer.

Mineral elements analyzed in this study (Al, B, Ba, Cd, Co, Cr, Cu, Fe, Li, Mn, Mo, Ni, Pb, Sr, Ti, V and Zn) are characterized by different solubility and availability to plants in relation to soil reaction (pH) as it was previously shown by Tyler and Olsson

Table 2. Relation between Al, B, Ba, Cd, Co, Cr, Cu and Fe content in soil and carrot cultivated in field experiments (mean from 2008–2009)
Tabela 2. Zależność pomiędzy zawartością Al, B, Ba, Cd, Co, Cr, Cu i Fe w glebie oraz w marchwi uprawianej w doświadczeniach polowych (średnie z lat 2008–2009)

Element Pierwiastek	Method of soil extraction – mean content of element in soil Metoda ekstrakcji gleby – średnia zawartość pierwiastka w glebie (x) Soil layer – warstwa gleby 0–30¹ cm			Content of element in carrot mg·kg⁻¹ d.w. Zawartość pierwiastka w marchwi mg·kg⁻¹ s.m. (y)	Method of soil extraction – mean content of element in soil Metoda ekstrakcji gleby – średnia zawartość pierwiastka w glebie (x) Soil layer – warstwa gleby 30–60¹ cm			Content of element in carrot mg·kg⁻¹ d.w. Zawartość pierwiastka w marchwi mg·kg⁻¹ s.m. (y)	Method of soil extraction – mean content of element in soil Metoda ekstrakcji gleby – średnia zawartość pierwiastka w glebie (x) Soil layer – warstwa gleby 60–90¹ cm			Content of element in carrot mg·kg⁻¹ d.w. Zawartość pierwiastka w marchwi mg·kg⁻¹ s.m. (y)
	A (mg·dm⁻³)	A² (mg·kg⁻¹)	B (mg·kg⁻¹)		A (mg·dm⁻³)	A² (mg·kg⁻¹)	B (mg·kg⁻¹)		A (mg·dm⁻³)	A² (mg·kg⁻¹)	B (mg·kg⁻¹)	
Al	7.09 (0.55*)	4.44 (0.55*)	1 250.09 (-0.26*)	43.90	2.87 (0.77*)	1.79 (0.77*)	1 371.27 (0.12)	50.52	0.62 (0.44*)	0.39 (0.44*)	1 583.01 (-0.64*)	50.52
B	0.65 (0.53*)	0.41 (0.53*)	1.81 (-0.40*)	26.28	0.64 (0.94*)	0.40 (0.94*)	1.32 (-0.45*)	26.12	0.42 (0.92*)	0.26 (0.92*)	0.64 (-0.44*)	26.12
Ba	1.76 (0.73*)	1.10 (0.73*)	50.52 (0.20*)	27.14	2.01 (0.68*)	1.26 (0.68*)	52.21 (-0.06)	28.00	2.01 (0.68*)	1.26 (0.68*)	64.83 (-0.69*)	28.00
Cd	0.02 (0.64*)	0.01 (0.65*)	1.04 (-0.09)	1.51	0.01 (0.41*)	0.006 (0.41*)	0.78 (-0.54*)	1.53	0.003 (0.32*)	0.002 (0.31*)	0.44 (-0.70*)	1.53
Co	n.d./b.d.	n.d./b.d.	1.69 (-) (0.06)	0.10	n.d./b.d.	n.d./b.d.	1.59 (-) (-0.39*)	0.06	n.d./b.d.	n.d./b.d.	1.20 (-) (-0.23)	0.06
Cr	0.003 (-0.02)	0.002 (-0.05)	1.42 (0.36*)	0.35	0.002 (0.49*)	0.001 (0.50*)	1.46 (0.25)	0.21	0.002 (0.33*)	0.001 (0.33*)	1.42 (0.07)	0.21
Cu	0.06 (0.69*)	0.04 (0.69*)	5.44 (-0.22*)	6.29	0.05 (0.86*)	0.03 (0.86*)	7.70 (0.05)	6.31	0.03 (0.66*)	0.02 (0.67*)	7.17 (-0.45*)	6.31
Fe	1.13 (0.04)	0.70 (0.04)	1 994.18 (-0.08)	44.41	0.78 (0.19)	0.49 (0.19)	2 050.14 (-0.35*)	42.17	0.28 (0.23)	0.18 (0.23)	2 253.94 (-0.42*)	42.17

Correlation coefficient (r) – x versus y – Współczynnik korelacji (r) x względem y

¹For soil layer – dla warstwy: 0–30 cm n = 112, 30–60 cm n = 48, 60–90 cm n = 48.
²Values recalculated from (mg·dm⁻³) to (mg·kg⁻¹) – Wartości przeliczone z (mg·dm⁻³) na (mg·kg⁻¹)
A – 0,03 M CH₃COOH, B – 1 M HCl. * – Correlation coefficient significant for P ≤ 0,05 – Współczynnik korelacji istotny dla P ≤ 0,05.
n.d. – no data available – soil content of element after extraction using 0.03 M CH₃COOH below the limits of detection by ICP-OES spectrometer
b.d. – brak danych – zawartość pierwiastka w glebie po ekstrakcji 0,03 M CH₃COOH poniżej limitu detekcji spektrometru ICP-OES.

Table 3. Relation between Li, Mn, Mo, Ni, Pb, Sr, Ti, V and Zn content in soil and carrot cultivated in field experiments (mean from 2008–2009)

Tabela 3. Zależność pomiędzy zawartością Li, Mn, Mo, Ni, Pb, Sr, Ti, V and Zn w glebie oraz w marchwi uprawianej w doświadczeniach polowych (średnie z lat 2008–2009)

Element Pierwiastek	Method of soil extraction – mean content of element in soil Metoda ekstrakcji gleby – średnia zawartość pierwiastka w glebie (x) Soil layer – warstwa gleby 0–30 cm			Content of element in carrot mg·kg⁻¹ d.w. Zawartość pierwiastka w marchwi mg·kg⁻¹ s.m. (y)	Method of soil extraction – mean content of element in soil Metoda ekstrakcji gleby – średnia zawartość pierwiastka w glebie (x) Soil layer – warstwa gleby 30–60 cm			Content of element in carrot mg·kg⁻¹ d.w. Zawartość pierwiastka w marchwi mg·kg⁻¹ s.m. (y)	Method of soil extraction – mean content of element in soil Metoda ekstrakcji gleby – średnia zawartość pierwiastka w glebie (x) Soil layer – warstwa gleby 60–90 cm			Content of element in carrot mg·kg⁻¹ d.w. Zawartość pierwiastka w marchwi mg·kg⁻¹ s.m. (y)
	A (mg·dm⁻³)	A² (mg·kg⁻¹)	B (mg·kg⁻¹)		A (mg·dm⁻³)	A² (mg·kg⁻¹)	B (mg·kg⁻¹)		A (mg·dm⁻³)	A² (mg·kg⁻¹)	B (mg·kg⁻¹)	
Li	0.02	0.01	0.64	0.05	0.02	0.01	0.83	0.05	0.02	0.01	0.90	0.05
(r)	(0.16)	(0.16)	(-0.32*)		(0.48*)	(0.49*)	(-0.17)		(0.54*)	(0.54*)	(-0.54*)	
Mn	1.20	0.75	278.78	8.27	0.59	0.37	242.48	8.48	0.32	0.20	181.85	8.48
(r)	(0.73*)	(0.73*)	(0.005)		(0.11)	(0.11)	(-0.47*)		(0.26)	(0.26)	(-0.39*)	
Mo	n.d./b.d.	n.d./b.d.	0.75	0.11	n.d./b.d.	n.d./b.d.	0.63	0.13	n.d./b.d.	n.d./b.d.	1.03	0.13
(r)	(-)	(-)	(-0.73*)		(-)	(-)	(-0.61*)		(-)	(-)	(-0.59*)	
Ni	0.07	0.05	3.03	0.81	0.08	0.05	3.37	0.62	0.04	0.03	2.92	0.62
(r)	(-0.08)	(-0.09)	(0.13)		(0.48*)	(0.48*)	(0.45*)		(0.74*)	(0.74*)	(-0.07)	
Pb	n.d./b.d.	n.d./b.d.	34.34	0.20	n.d./b.d.	n.d./b.d.	58.99	0.19	n.d./b.d.	n.d./b.d.	25.11	0.19
(r)	(-)	(-)	(-0.11)		(-)	(-)	(-0.47*)		(-)	(-)	(0.01)	
Sr	2.51	1.57	13.61	12.97	2.62	1.64	12.16	13.84	1.86	1.16	8.15	13.84
(r)	(0.89*)	(0.89*)	(0.16)		(0.94*)	(0.94*)	(-0.10)		(0.94*)	(0.94*)	(-0.75*)	
Ti	4.48	2.80	7.84	2.15	2.75	1.72	9.98	2.36	1.64	1.02	10.18	2.36
(r)	(-0.31*)	(-0.31*)	(-0.12)		(-0.01)	(-0.01)	(-0.24)		(0.06)	(0.06)	(-0.03)	
V	n.d./b.d.	n.d./b.d.	6.97	0.09	n.d./b.d.	n.d./b.d.	5.70	0.08	n.d./b.d.	n.d./b.d.	3.95	0.08
(r)	(-)	(-)	(0.12)		(-)	(-)	(-0.22)		(-)	(-)	(-0.03)	
Zn	1.79	1.12	53.89	35.12	1.00	0.62	40.83	32.16	0.32	0.20	25.82	32.16
(r)	(0.33*)	(0.33*)	(-0.16)		(0.53*)	(0.53*)	(-0.50*)		(0.33*)	(0.33*)	(-0.54*)	

Correlation coefficient (r) – x versus y – Współczynnik korelacji (r) x względem y

1 – see table 2 – patrz tabela 2

[2001]. Thus, for assessment of 0.03 M CH_3COOH usefulness for standard soil determination not only of macro elements and boron but also other trace elements there is a need for detailed studies on soils with diversified physicochemical properties. What is more, complex assessment of macro- and microelement nutrition of plants as well as the estimation of mineral uptake in plant tissues should be included in proposed research.

CONCLUSIONS

Soil content of Al, B, Ba, Cd, Cu, Sr and Zn analyzed in 0.03 M CH_3COOH (in layers: 0–30 cm, 30–60 cm, 60–90 cm) as well as Cr, Li and Ni (in layers: 30–60 cm and 60–90 cm) were correlated in a relatively stronger way with its accumulation in carrot roots in comparison with determination using 1 M HCl.

Assessment of tested elements in soil samples after 1 M HCl extraction revealed a significant relation between soil concentration of: Mn and Fe (for 30–60 cm and 60–90 cm soil layers), Co and Pb (for 30–60 cm layer) as well as Mo (for 0–30 cm, 30–60 cm and 60–90 cm layers) and its content in carrot storage roots.

No relation was found between V content in soil (extracted using 1 M HCl) and its accumulation in carrot roots.

A significant dependence was found between tested soil extraction procedures (0.03 M CH_3COOH and 1 M HCl) in reference to determination of: B and Ti in all three soil layers (0–30 cm, 30–60 cm and 60–90 cm); Ba, Cu and Li in layers: 0–30 cm and 60–90 cm; Cd, Ni and Zn in 0–30 cm soil layer as well as Al, Fe, Mn and Sr in 60–90 cm layer.

Soil level of Co, Mo, Pb and V after 0.03 M CH_3COOH was below the limits of detection using ICP-OES spectrometer.

REFERENCES

Chłopecka A., 1994. Wpływ różnych związków kadmu, miedzi, ołowiu i cynku na formy tych metali w glebie oraz na ich zawartość w roślinach. IUNG Seria R, Puławy.

Davies B.E., 1992. Inter-relationships between soil properties and the uptake of cadmium, copper, lead and zinc from contaminated soils by radish (*Raphanus sativus* L.). Water Air Soil Poll. 63, 331–342.

Gorlach E., Curyło T., Gambuś F., Grzywnowicz I., Jasiewicz C., Kopeć M., Mazur B., Olkuśnik S., Rogóż A., Wiśniowska-Kielian B., 1999. Przewodnik do ćwiczeń z chemii rolnej. Wyd. AR w Krakowie.

Houba V.J.G., Novozamsky I., Temminghoff E., 1997. Soil analysis procedures. Extraction with 0.01 M $CaCl_2$ (Soil and Plant Analysis, Part 5A). Wageningen Agricultural University, The Netherlands.

Komosa A., 2000. Nowoczesne diagnozowanie potrzeb nawozowych roślin sadowniczych. Mat. konf. VIII Ogólnopolskiej Konferencji Naukowej pt. „Efektywność Stosowania nawozów w uprawach ogrodniczych. Zmiany ilościowe i jakościowe w warunkach stresu. Warszawa 20–21 czerwca 2000, 11–16.

Komosa A., Stafecka A., 2002. Zawartości wskaźnikowe składników pokarmowych dla gleb sadowniczych analizowanych metodą uniwersalną. Rocz. AR w Poznaniu, Ogrod. 35, 105–116.

Lindsey W.L., Schwab A.P., 1982. The chemistry of iron in soils and its availability to plants. J. Plant Nutr. 5, 821–840.

McLaughlin M.J., Maier N.A., Rayment G.E., Sparrow L.A., Berg G., Mckay A., Milham P., Merry R.H., Smart M.K., 1997. Cadmium in Australian potato tubers and soils. J. Environ. Qual. 26, 1644–1649.

Nowak J.S., Strojny Z., 2004. Metody analizy chemicznej podłoży ogrodniczych stosowane w Holandii i w Niemczech w celach diagnostycznych. Rocz. AR w Poznaniu 356, Ogrod. 37, 255–259.

Nowosielski O. 1974. Metody oznaczania potrzeb nawożenia. Wyd. II, PWRiL, Warszawa.

Pasławski P., Migaszewski Z.M., 2006. The quality of element determinations in plant materials by instrumental methods. Polish J. Environ. Stud. 15(2a) Part I, 154–164.

Quevauviller P., Rauret G., Muntau H., Ure A.M., Rubio R., López-Sánchez J.F., Fiedler H.D., Griepink B., 1994. Evaluation of a sequential extraction procedure for the determination of extractable trace metal contents in sediments. Fresenius J. Anal. Chem. 349, 808–814.

Sady W., 2006. Nawożenie warzyw polowych. Plantpress, Kraków.

Sady W., Rożek S., Domagała I., Kołodziej M., 1998. Porównanie metod ekstrakcji Cu, Zn, Mn, Fe, i Cd z gleb o zróżnicowanych właściwościach fizykochemicznych. Zesz. Nauk. AR w Krakowie 333 (57), 833–836.

Sękara A., Poniedziałek M., 1999. Akumulacja metali ciężkich przez wybrane warzywa korzeniowe uprawiane wokół aglomeracji krakowskiej. Część I – kadm, miedź, ołów i cynk. Zesz. Prob. Post. Nauk Roln. 466, 397–411.

Smoleń S., 2009. Wpływ nawożenia jodem i azotem na skład mineralny marchwi. Ochr. Środ. i Zas. Nat. 40, 286–292.

Smoleń S., Sady W., 2006. The content of Cd, Cu and Zn in carrot storage roots as related to differentiated nitrogen fertilization and foliar nutrition. Polish J. Envir. Stud. 15 (2A, Part II), 503–509.

Smoleń S., Sady W., 2007a. The effect of nitrogen fertilizer form and foliar application on Cd, Cu and Zn concentrations in carrot. Folia Hort. 19 (1), 87–96.

Smoleń S., Sady W., 2007b. Wpływ nawozu azotowego z inhibitorem nitryfikacji oraz dokarmiania dolistnego na zawartość suchej masy, Cd, Cu i Zn w marchwi. Ochr. Środ. i Zas. Nat. 32: 81–86.

Smoleń S., Sady W., 2008. The effect of foliar nutrition with nitrogen, molybdenum, sucrose and benzyladenine on the contents of dry weight, Cd, Cu and Zn in carrot. Veget. Crops Res. Bull. 68, 135–144.

Smoleń S., Sady W., 2009. The effect of nitrogen fertilizer form and foliar application on concentrations of twenty five elements in carrot. Folia Hort. 21 (1), 3–16.

Strojny Z., Nowak J.S., 2004. Zasady metodyki analizy chemicznej podłoży ogrodniczych przyjętej przez Unię Europejską. Rocz. AR w Poznaniu 356, Ogrodnictwo 37, 279–286.

Tyksiński W., 1985. Reakcja sałaty szklarniowej uprawianej w torfie na zróżnicowane nawożenie mikroelementami. Cz. II. Zmiany zawartości mikroelementów w podłożu. Prace Kom. Nauk Roln.i Leś., 59, 243–251.

Tyler G., Olsson T., 2001 Concentrations of 60 elements in the soil solution as related to the soil acidity. Europ. J. Soil Sci. 52, 151–165.

Westerman R.L., 1990. Soil testing and plant analysis. 3rd edition. Soil. Sci. Soc. Amer., Madison, Wi.

RELACJE ILOŚCIOWE MIĘDZY ZAWARTOŚCIĄ WYBRANYCH PIERWIASTKÓW ŚLADOWYCH W GLEBIE EKSTRAHOWANYCH 0,03 M CH₃COOH I 1 M HCL A ZAWARTOŚCIĄ ICH FORM OGÓLNYCH W KORZENIACH SPICHRZOWYCH MARCHWI

Streszczenie. Istnieje potrzeba poszukiwania szybkich i łatwych do wykonania metod analizy zawartości składników glebach, opartych na wspólnej ekstrakcji wielu składników. Zawartość składników oznaczona w glebach za pomocą tych metod korelowała z ich zawartością w roślinach. Liczne badania wykazały, że zawartość mikroelementów, metali ciężkich oraz pierwiastków śladowych w glebie oznaczana za pomocą 0.01 M CaCl₂ nie odzwierciedla zawartości tych składników w warzywach. Celem badań było określenie zależności pomiędzy zawartością w glebie Al, B, Ba, Cd, Co, Cr, Cu, Fe, Li, Mn, Mo, Ni, Pb, Sr, Ti, V i Zn ekstrahowanych za pomocą 0,03 M CH₃COOH i 1 M HCl, a ich zawartością w korzeniach spichrzowych marchwi. W latach 2008–2009 badaniami objęto próby gleby (z warstw 0–30 cm, 30–60 cm i 60–90 cm) po uprawie marchwi oraz próby korzeni spichrzowych marchwi z uprawy polowej prowadzonej na tym samym stanowisku glebowym. Łącznie analizie składu chemicznego (pod względem zawartości badanych pierwiastków) poddano 112 prób korzeni spichrzowych marchwi i 112 prób gleby z warstwy 0–30 cm oraz po 48 prób gleby z warstw 30–60 cm i 60–90 cm. Badania wykazały większą przydatność ekstrakcji gleby 0,03 M CH₃COOH (standardowo służącej do określania zawartości makroskładników chlorków i boru) niż ekstrakcji 1 M HCl do oceny związku pomiędzy zawartością Al, B, Ba, Cd, Cr, Cu, Li, Ni, Sr, Ti i Zn w glebie a zawartością tych pierwiastków w korzeniach spichrzowych marchwi. Zastosowanie ekstrakcji 1 M HCl dało stosunkowo lepsze rezultaty niż ekstrakcja 0,03 M CH₃COOH w zakresie wielkości współczynników korelacji pomiędzy zawartością Co, Fe, Mn, Mo i Pb w glebie i marchwi. Zawartość Co, Mo, Pb i V w glebie po ekstrakcji 0,03 M CH₃COOH była niższa od limitu detekcji spektrometru ICP-OES. Nie wykazano związku pomiędzy zawartością wanadu w glebie (oznaczanego w 1 M HCl) a zawartością V w korzeniach spichrzowych marchwi.

Słowa kluczowe: 0,03 M kwas octowy, 1 M kwas solny, pierwiastki śladowe, marchew