ACTA SCIENTIARUM POLONORUM Hortorum Cultus 1(1) 2002, 13-22

EFFECT OF NICKEL ON YIELDING AND MINERAL COMPOSITION OF THE SELECTED VEGETABLES

Renata Matraszek, Maria Szymańska, Małgorzata Wróblewska

Abstract. Over the three-year pot experiment the investigations were made on nickel influence on yielding and mineral composition (K, Ca, Mg, P, Fe and Ni content) of lettuce and spinach leaves as well as zucchini and bean fruits. The experiment was differentiated regarding nickel content ($NiSO_4 \cdot 7H_2O$) introducing: 0 (control); 10; 40 and 60 mg $Ni \cdot kg^{-1}$ sand, at the same time considering various nutritive requirements of the plant species studied. The obtained results indicate that even the lowest nickel dose applied (10 mg $Ni \cdot kg^{-1}$ substrate) has caused a significant decrease of yield of the usable parts of lettuce, spinach, zucchini and bean. Further increase of nickel content in the substrate (40–60 mg $Ni \cdot kg^{-1}$) resulted in more intensive yield drop of lettuce and spinach leaves.

Under such conditions due to improper generative development, no generative yield of zucchini and bean was obtained. Nickel at amount 10 mg $Ni \cdot kg^{-1}$ substrate affected the significant growth of potassium concentration in the leaves of lettuce, phosphorus in spinach leaves, while it decreased phosphorus and potassium concentration in the zucchini and bean fruits causing at the same time significant fall in magnesium content in zucchini fruits and increase in Mg concentration in bean pods. Nickel dose growth in the substrate has differentiated changes in the plant mineral composition to a greater extent. Nickel at amount 10 mg $Ni \cdot kg^{-1}$ substrate influenced a significant iron growth in spinach leaves, zucchini fruits and bean pods, whereas it decreased Fe content in lettuce biomass. Increased nickel doses have reduced Fe concentration significantly in the usable organs of the vegetable species examined. Generally the growing nickel quantity in substrate affected the successive increase of this metal content in the usable organs of the vegetable species investigated.

Key words: lettuce, spinach, zucchini, bean, concentrations of K, Ca, Mg, P, Fe, Ni

INTRODUCTION

Nickel belongs to metals showing considerable mobility, in particular at acid soil environment. Excessive accumulation of nickel in soils, apart from direct harmfulness to soil flora and fauna, is conducive to this trace element collection in plant biomass and its inclusion into trophic chain by the food crop [Sauerbeck 1989, Małysz 1991, Gębski 1998]. Out of plants grown, the leafy vegetables demonstrate great metal accumulation capacity, sometimes a few times higher compared to tuber crops and grain crops [Lübben and Sauerbeck 1991, Terelak et al. 1995, Kabata-Pendias and Pendias 1999]. Besides, vegetables are an important source of mineral elements and make a basic component of man diet substantial from a quantitative point of view – around 50% [Niklińska and Maryański 1988, Curyło 1997].

The objective of the studies carried out was assessment of nickel effect on yielding and mineral composition of usable organs of selected vegetable species.

MATERIAL AND METHODS

The examination object was made by four plant species of vegetables, two of them with leaves as usable organs (*Lactuca sativa* L. cv. Syrena *Cichoriaceae* family, *Spinacia oleracea* L. cv. Markiza F_1 *Chenopodiaceae* family), while the other two with generative organs – spurious berry (*Cucurbita pepo* conv. *giromontiina* L. cv. Soraya *Cucurbitaceae* family) and pod (*Phaseolus vulgaris* L. cv. Złota Saxa *Fabaceae* family). A vegetative part of the experiment was run in the plant house of the Department of Plant Physiology Agricultural University in Lublin with solid culture method in the pots of 3 kg quartz sand each. The mineral components were introduced into all the pots in the following amount and form: P – 250 (KH_2PO_4); Mg – 300 ($MgCl_2$); Ca – 800 ($CaCO_3$) and Fe – 30 (citrate Fe^{2+}) mg per pot. The other microelements were supplemented with 1% A-Z solution in quantity 1,5 cm^3 per pot. Owing to various requirements of the vegetable species examined concerning nitrogen and potassium nutrition, the zucchini plants were administered nitrogen in amount 800 mg, while the other species, excluding bean, were given 700 mg of N per pot. The bean plants were supplied with a starting dosage only – 80 mg N per pot. At the same time the bean roots were inoculated with active strain of bacteria *Rhizobium* F65 obtained from the Subdepartment of Microbiology IUNG in Puławy. A potassium dose for zucchini was 800, whereas for the other species of plants – 600 mg K per pot. The above macroelements were introduced in form of NH_4NO_3, K_2SO_4 and KH_2PO_4.

A factor differentiating this experiment was nickel content: 0 (control); 10; 40 and 60 mg $Ni \cdot kg^{-1}$ sand ($NiSO_4 \cdot 7H_2O$). For each plant species under investigation the experiment included 4 series, each comprising 6 replications and 3 repetitions at time. At experiment set and after plant collection there was determined substrate pH that ranged 5.8 and 5.2 respectively.

In the successive years the studies on vegetable crop were made in the phase of full consumer ripeness of plants from control (0 mg $Ni \cdot kg^{-1}$ substrate) and at the same time yield of fresh and dry mass of usable organs was fixed in the examined species. Dry plant material was analysed chemically and there was established the content of phosphorus with colorimetric vanadic-molibdenic method, magnesium content by colorimetric method with titan yellow use, potassium and calcium – by photoflame method (ASA). After dry premineralization of the material there was determined nickel and iron content using absorption atomic spectrophotometry (ASA) on the apparatus Philips PU 9100X model. There were calculated quantitative ratios between the content of Ca:P, Ca:Mg, K:Mg and Fe:Ni. The data regarding crop and mineral composition were analysed statistically calculating the lowest significant difference. Considering the similar results obtained in each experimental year the data presented in the tables and diagrams (tab. 1, 2; fig. 1–4) are the means of the values gained from the three-year investigations.

RESULTS AND DISCUSSION

Nickel content in the light soil for cultivation should not exceed 30, in the heavy ones 100 mg·kg^{-1} d.m. [Monitor Polski 1986]. According to Kabata-Pendias and Pendias [1999] maximum nickel content limit in the arable soil is 100 mg·kg^{-1}, while the other authors [acc. to Klocky after Gorlach et al. 1994] claim 50 mg Ni·kg^{-1} soil to be the highest admissible (threshold) content. This value is recognised by Kabata-Pendias et al. [1993] as the maximum nickel content limit accepted natural, i.e. characterising the soil non-contaminated with this metal. In that case the present experiment concentrated on the reaction of the selected vegetables to nickel at the concentrations oscillating within the values considered natural and acceptable for arable soils.

One of measurable indices demonstrating the effect of the environment contaminated with metals on plants is yield decrease and mineral composition. From the data presented in table 1, it appears that the lowest nickel concentration applied in the experiment (10 mg·kg^{-1} substrate) resulted in significant yield reduction of fresh and dry weight of lettuce heads by 8 and 8% respectively, spinach leaves by 32 and 30%, zucchini fruits by 78 and 23% and fresh weight of bean pods by 14%. Changes of bean fruit dry mass was statistically insignificant.

Table 1. Yield of the vegetable species usable parts
Tabela 1. Plon części użytkowych badanych gatunków warzyw

Dose Ni (mg·kg^{-1} substrate) Dawka Ni (mg·kg^{-1} podłoża)	Lettuce leaves Liście sałaty		Spinach leaves Liście szpinaku		Zucchini fruits Owoce cukini		Bean fruits Owoce fasoli	
	Fresh weight Świeża masa	Dry weight Sucha masa	Fresh weight Świeża masa	Dry weight Sucha masa	Fresh weight Świeża masa	Dry weight Sucha masa	Fresh weight Świeża masa	Dry weight Sucha masa
0	64.99	6.30	63.10	7.10	154.89	9.67	9.87	1.48
10	59.53	5.79	43.00	4.97	34.39	7.45	8.46	1.54
40	45.52	4.78	6.63	1.09	-	-	-	-
60	13.96	1.73	5.83	1.25	-	-	-	-
$LSD_{0.05}$	2.16	0.19	6.14	1.70	8.56	0.50	0.20	0.13

- lack of generative yield
- brak plonu generatywnego

Nickel content growth in the substrate from 40 (series III) to 60 (series IV) mg Ni·kg^{-1} substrate deepened yield efficiency decrease of the lettuce and spinach usable parts. Drop in fresh and dry mass of the lettuce leaves was 30 and 24% respectively (series III – 40 mg Ni·kg^{-1}) and 79 and 73% (series IV – 60 mg Ni·kg^{-1}). For the spinach leaves the values were 89 and 85% (series III) and 91 and 82% (series IV). At the nickel contents higher than 10 mg Ni·kg^{-1} substrate due to improper generative development of zucchini and bean (flower buds formed did not reach full blossom state or fell off relatively early) no generative yield was obtained (tab. 1).

Summing up, the value of fresh and dry weight of usable yield of lettuce, spinach, zucchini and bean pod fresh mass has reduced significantly at even the lowest nickel dose applied in the experiment (10 mg Ni·kg^{-1} substrate). In that case nickel contents in soil considered natural by Kabata-Pendias and Pendias [1999] should be specified accurately for the vegetable species studied. High significant drop of vegetable yield, spinach in particular, may result from relatively easy nickel translocation with simultaneous limited iron transport to the green tops. Terelak and Piotrowska [1997] claim that relatively low mean natural nickel content (6.7 mg·kg^{-1}) in the Polish soils showing light granulometric composition in top layers issues from a fact that soils rich in a colloidal fraction demonstrate higher concentration of this element (around 22 mg·kg^{-1}) compared to the light ones. The highest nickel concentration was stated for the western and southern provinces and the maximum values of the mean nickel contents, i.e. 20 mg·kg^{-1} were recorded in the former Krosno, Bielskie and Nowosądeckie Province [Kabata-Pendias and Pendias 1999]. Evaluation of the nickel content state in the soils of Poland basing on the principles of IUNG [Kabata-Pendias et al. 1993] proved that soil percentage with raised nickel contamination level is slight. It means that certain limitations in plant cultivation due to soil pollution with nickel may regard small cropland area indeed. However, the regions showing higher than natural soil nickel content often make adjacent gardens where vegetables are grown.

Dry material of plant usable parts analysed for P, K, Mg and Ca content revealed differentiated concentration of each mineral component regarding a species, organ as well as nickel content in the soil. Nickel content in amount 10 mg·kg^{-1} in the substrate (series II) affected statistically significant increase of potassium concentration in lettuce leaves (by 25%), whereas in spinach leaves there was stated K content drop at the significance limit with simultaneous significant phosphorus concentration growth (by 9%) (tab. 2). The mentioned nickel dose caused significant decrease of phosphorus and potassium concentration in zucchini fruits (by 17 and 47% respectively) and bean pods (by 7 and 3%). At the same time there was recorded significant fall of magnesium content in zucchini fruits (by 36%) and significant growth of this macroelement in bean fruits (by 10%). At the lowest nickel concentration applied in the experiment (10 mg Ni·kg^{-1}) there were no statistically significant differences of calcium content in the usable organs of the vegetable species investigated (tab. 2).

Under the conditions of higher nickel doses, i.e. 40 (series III) and 60 (series IV) mg Ni·kg^{-1} substrate the mineral composition of lettuce and spinach leaves shaped differentially. In the lettuce leaves significant increase of phosphorus, potassium and calcium by 22, 47 and 47% (series III) and 339, 48 and 23% (series IV) was recorded. Phosphorus content growth in the plants at nickel presence was confirmed in the professional literature [Vergnano 1953, Crooke et al. 1954] providing that the bigger nickel dose the higher phosphorus concentration in plants is. Palocis et al. [1998] investigated nickel effect on tomato plants and observed a clear positive interaction between nickel and potassium – a high nickel level in the medium increased potassium concentration in tomato biomass. In the present authors' own studies a similar relation was fixed in lettuce leaves, yet definitely different reaction in spinach leaves. In the spinach leaves potassium content in the series III and IV and magnesium in the series IV trended significantly downwards (by 21, 34 and 11% respectively), while calcium content in the series III grew significantly (by 26% – tab. 2). That corresponds to Crooke's [1955] and Palocis et al. [1998] studies showing that nickel excess increases significantly calcium content in oats plants, however it reduces magnesium and iron concentration. Rise of K, Ca and especially P concentration in lettuce leaves due to nickel threshold dose may result from a significant yield decrease of the organs, that is accumulation of the ions taken up in small biomass or less so from more intensive ion uptake. This interpretation of the results is also confirmed by other reports on nickel occurrence in the antagonistic system with Ca, P, K and Mg [Mengel and Kirkby 1983, Szymańska et al. 1997, Graczyk et al. 1999]. The results obtained from the present authors' own studies also indicate that e.g. use of 60 mg Ni·kg^{-1} in the substrate there was recorded 73% drop of dry mass yield of lettuce leaves, at the same time in these organs very great growth of phosphorus content by 339% was noted. However, potassium and calcium concentration rose by 48 and 23% respectively (tab. 1, 2).

Table 2. Mineral component content in the usable parts of the vegetable species examined
Tabela 2. Zawartość składników mineralnych w częściach użytkowych badanych warzyw

Organs Organy	Dose Ni, mg·kg^{-1} substrate Dawka Ni, mg·kg^{-1} podłoża	Content – Zawartość					
		% d.w.; % s.m.				mg·kg^{-1} d.w.;mg·kg^{-1} s.m.	
		K	Ca	Mg	P	Fe	Ni
Lettuce leaves Liście sałaty	0	1.74	0.30	0.58	0.93	156.1	Did not detect Nie stwierdzono
	10	2.17	0.32	0.50	1.05	84.6	1.48
	40	2.56	0.44	0.52	1.13	49.1	1.93
	60	2.58	0.37	0.63	4.08	43.4	2.29
$LSD_{0.05}$		0.17	0.07	0.09	0.19	5.69	0.32
Spinach leaves Liście szpinaku	0	5.38	0.86	0.65	0.53	206.0	Did not detect Nie stwierdzono
	10	4.99	0.72	0.63	0.58	229.0	1.21
	40	4.27	1.08	0.67	0.52	157.0	3.14
	60	3.54	0.64	0.58	0.50	96.0	2.64
$LSD_{0.05}$		0.39	0.24	0.04	0.04	8.82	0.54
Zucchini fruits Owoce cukini	0	2.94	0.13	0.28	1.62	64.0	Did not detect Nie stwierdzono
	10	1.57	0.12	0.18	1.34	77.6	1.2
	40	-	-	-	-	-	-
	60	-	-	-	-	-	-
$LSD_{0.05}$		0.08	0.02	0.09	0.10	4.3	
Bean fruits Owoce fasoli	0	6.08	0.19	0.30	0.43	91.0	Did not detect Nie stwierdzono
	10	5.90	0.19	0.33	0.40	105.3	0.09
	40	-	-	-	-	-	-
	60	-	-	-	-	-	-
$LSD_{0.05}$		0.13	0.01	0.02	0.03	2.6	

- lack of generative yield
- brak plonu generatywnego

Regarding a nickel content in the environment there were determined clear changes in iron concentration in usable organs biomass of the vegetables examined. Increasing nickel doses in the substrate (10, 40 and 60 mg Ni·kg^{-1}) resulted in significant Fe concentration drop in lettuce leaves by 46, 69 and 72%. In spinach leaves in series II (10 mg Ni·kg^{-1} substrate) a significant growth of iron concentration was obtained (by 11%), while Fe content in the plants from series III and IV fell significantly (by 24 and 53% respectively). The lowest nickel content examined in the experiment (10 mg Ni·kg^{-1} substrate) influenced significant Fe concentration rise in biomass of zucchini and bean fruits by 21 and 16%, respectively (tab. 2).

Growing nickel quantities in the soil of the leafy vegetables studied affected statistically significant increase of its content in biomass. Generally spinach leaves than lettuce ones showed higher nickel content, irrespective of its concentration in the substrate. The highest Ni content in the lettuce leaves was recorded in series IV (2.29 mg Ni·kg^{-1} d.m.) while in the spinach leaves in the series III (3.14 mg Ni·kg^{-1} d.m.). Application of 10 mg Ni·kg^{-1} substrate resulted in higher nickel content in zucchini fruits compared to bean pods by 1.2 and 0.9 mg Ni·kg^{-1} d.m. (tab. 2). Admissible nickel content in the usable plants is not defined legitimately or formulated in the Government Gazette, while so called daily dose tolerated by man (ADI) has been worked out. According to the WHO standards the ADI values for nickel (25–35 µg daily·70 kg bm.$^{-1}$) are very low and they are comparable with values for Cd and Pb [WHO 1972, WHO 1989, Martyn et al. 1998, Kabata-Pendias and Pendias 1999]. Therefore taking into account the results of the present studies in order to surpass a daily dose tolerated one should consume over 243 g lettuce or 250 g spinach or 135 g zucchini fruits and 2136 g bean pods obtained from the substrate with 10 mg Ni·kg^{-1}. However, there is some discrepancy between ADI and plant content considered innoxious. The nickel contents regarded harmless in plants are high and comparable to the contents of metals less toxic towards living organisms, e.g. Zn, Cu [WHO 1972, WHO 1989, Martyn et al. 1998, Kabata-Pendias, Pendias 1999]. Providing that nickel content in plants grown under conditions of "natural" content of this element in habitat did not exceed 5 mg·kg^{-1} [after Gambuś 1993] it can be thought that basing on present authors' own results in the vegetable usable parts this limit was not surpassed and nickel content was lower in the generative organs than in vegetative ones (tab. 2).

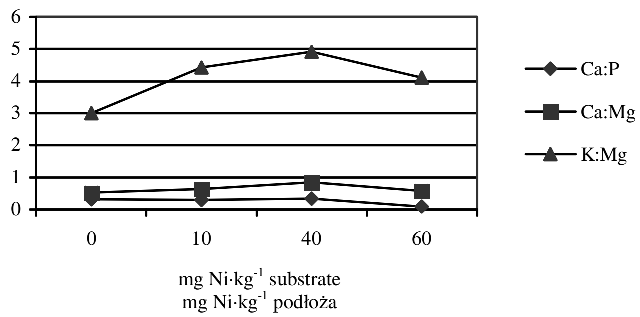

Fig. 1. Ca:P; Ca:Mg and K:Mg ratios in the leaves of lettuce
Rys. 1. Stosunki ilościowe Ca:P; Ca:Mg i K:Mg w liściach sałaty

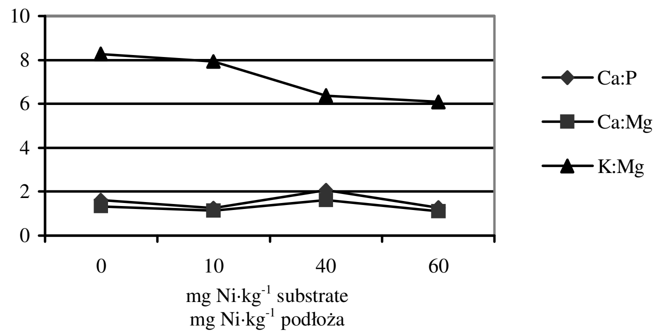

Fig. 2. Ca:P; Ca:Mg and K:Mg ratios in the leaves of spinach
Rys. 2. Stosunki ilościowe Ca:P; Ca:Mg i K:Mg w liściach szpinaku

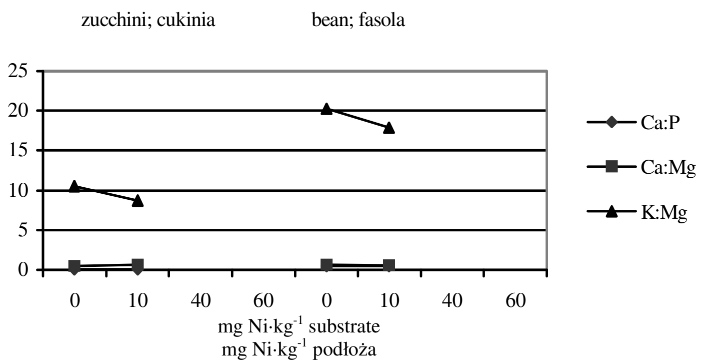

Fig. 3. Ca:P; Ca:Mg and K:Mg ratios in the zucchini and bean fruits
Rys. 3. Stosunki ilościowe Ca:P; Ca:Mg i K:Mg w owocach cukini i fasoli

The increasing nickel dose caused the changes in P, K, Ca and Mg content in the usable organs of examined vegetables and affected development of quantitative ratios between the elements. The values of ratios between Ca:P, Ca:Mg and K:Mg are also conditioned by a plant species and organ. The above ratios in the lettuce leaves and zucchini fruits, regardless nickel content in substrate, show lower value compared to the same parameters obtained for spinach leaves and bean pods (fig. 1–3). Higher magnesium concentration and much lower potassium ones in spinach leaves made considerable limitation of ratios with these cations, excluding series with 40 mg Ni·kg^{-1} substrate, in which value of the ratios increased. Moreover, spinach leaves from this series manifested the most regular ratio considering biological value between Ca:P [Stählin 1969, Kotowska and Wybieralski 1999]. Furthermore the doses higher than 40 mg Ni·kg^{-1}

substrate influenced both, the leaves of spinach and lettuce, causing substantial and unfavourable restriction of Ca:P ratio (fig. 1, 2). Opposite to spinach, in the lettuce leaves K:Mg ratio got expanded due to increasing nickel doses application. That issued from a slight Mg content growth with simultaneous significant K concentration rise. Among the cations discussed the least concentration changeability in the vegetative parts was demonstrated by Mg, while P – the highest. The changing quantitative ratio with magnesium share result from varying concentration of K or Ca.

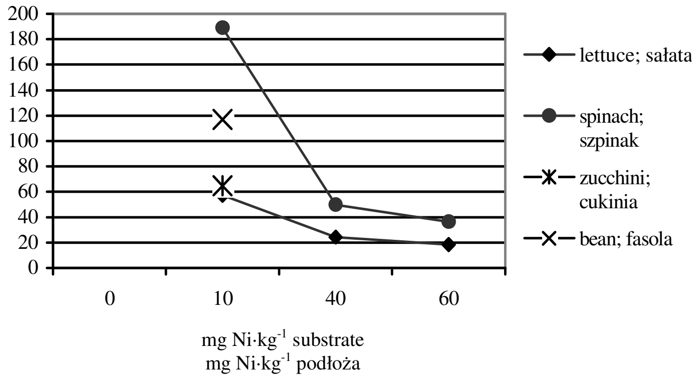

Fig. 4. Fe:Ni ratios in the usable parts of the vegetable examined species
Rys. 4. Stosunki Fe:Ni w częściach użytkowych badanych gatunków warzyw

Moreover this dependence was marked more clearly in the leaves of spinach than lettuce. Regarding potassium concentration fall in the fruits of zucchini and bean K:Mg ratio got narrowed (fig. 3). The digital relations of Fe:Ni ratio in the leaves of lettuce and spinach are very distant that is typical of the species characteristics of these vegetables, although the trends for both plants were identical (fig. 4). Considerable narrowing of Fe:Ni ratio for lettuce from 57 to 24 and spinach from 189 to 50 in the series II and III, i.e. within the range of quantities considered natural (to 40 $mg \cdot kg^{-1}$ substrate) indicate not only translocation disturbance but antagonism in both metals uptake as well.

CONCLUSIONS

1. Nickel in dose 10 $mg \cdot kg^{-1}$ substrate causes significant yield decrease of lettuce and spinach leaves as well as usable parts of zucchini and bean. Nickel dose growth in the substrate intensifies this process.

2. Nickel affects the changes in the mineral composition of lettuce, spinach, zucchini and bean usable parts. Nickel content in 10 mg $Ni \cdot kg^{-1}$ substrate influenced significantly potassium concentration increase in the lettuce leaves, phosphorus in the spinach leaves, while phosphorus and potassium concentration fall in the fruits of zucchini and bean caused at the same time significant drop of magnesium content in zucchini fruits and increase of Mg concentration in bean pods. Nickel dose growth in the substrate deepened the changes in the mineral composition related with potassium content increase in

the leaves of lettuce and fall of this element in the leaves of spinach, as well as increase of calcium and phosphorus content in the lettuce leaves and magnesium concentration drop in the spinach leaves.

3. Nickel in amount of 10 mg $Ni \cdot kg^{-1}$ substrate affected the significant growth of iron content in the leaves of spinach, zucchini fruits and bean pods, whereas it decreased Fe content in lettuce biomass. Increased nickel doses have reduced iron concentration significantly in the usable organs of the studied vegetables.

4. Increasing nickel quantities in the substrate (from 10 do 60 mg $Ni \cdot kg^{-1}$) influenced the successive nickel growth in the usable organs of the examined vegetables. However, the Ni contents accepted for plants grown in the conditions of "natural" nickel content have not been surprised.

5. Greater changes in the mineral compositions issued from nickel effect regard the vegetative parts and not generative ones.

REFERENCES

Crooke W. M., 1955. Further aspects of the relation between nickel toxicity and iron supply. Ann. Appl. Biol. 43, 465–476.

Crooke W. M., Hunter J. G., Vergnano O., 1954. The relationships between nickel toxicity and iron supply. Ann. Appl. Biol. 41, 311–324.

Curyło T., 1997. Zawartość metali ciężkich w warzywach z ogrodów działkowych w Tarnowie. Zesz. Probl. Post. Nauk Roln. 448, 35–42.

Gambuś F., 1993. Metale ciężkie w wierzchniej warstwie gleb i w roślinach regionu krakowskiego. Zesz. Nauk AR w Krakowie. Rozpr. hab. 176

Gębski M., 1998. Czynniki glebowe oraz nawozowe wpływające na przyswajanie metali ciężkich przez rośliny. Post. Nauk Roln. 5, 1–16.

Gorlach E., Gambuś F., Brydak K., 1994. Zawartość metali ciężkich w glebach i roślinach lądowych wokół Huty im. Tadeusza Sendzimira. Acta Agr. Silv. Agr. 32,13–24.

Graczyk A., Radomska K., Długaszek M., 1999. Synergizm i antagonizm między biopierwiastkami i metalami toksycznymi. Ochr. Śr. Zasobów Nat. 18, 39–45.

Kabata-Pendias A., Motowicka-Terelak T., Piotrowska M., Terelak H., Witek T., 1993. Ocena stopnia zanieczyszczenia gleb i roślin metalami ciężkimi i siarką. Wyd. IUNG Puławy. P(53), 20.

Kabata-Pendias A., Pendias H., 1999. Biogeochemia pierwiastków śladowych. Wyd. Nauk. PWN, Warszawa.

Kotowska J., Wybieralski J., 1999. Kształtowanie się stosunków ilościowych między K, Ca i Mg w glebie oraz roślinach. Biul. Magnezol. 4(1), 104–110.

Lübben S., Sauerbeck D., 1991. Transferfaktoren und Transferkoefizienten für den Schwermetallübergang Boden-Pflanze. Berichte aus der Ökologischen Forschung. 6, 180–223.

Małysz J., 1991. Bezpieczeństwo żywnościowe – strategiczna potrzeba ludzkości. Wyd. Nauk. PWN, Warszawa: 120–125.

Martyn W., Molas J. Onuch-Amborska J., 1998. Oddziaływanie hortisoli o różnej zawartości metali ciężkich na jakość biologiczną sałaty odmiany Bona. Zesz. Probl. Post. Nauk Roln. 461, 279–289.

Mengel K., Kirkby E. A., 1983. Podstawy żywienia roślin. PWNiR, Warszawa.

Monitor Polski, 1986. nr 23, poz. 170, 285.

Niklińska M., Maryański M., 1988. Metale ciężkie w warzywach. Aura. 88(4), 20–22.

Palocis G., Gomez J., Ccrbonell-Barrachuma A., Pedreno J. N., Mataix J., 1998. Effect of nickel on concentration on tomato plant nutrition and dry matter yield. J. Plant Nutrit. 21(10), 2179–2191.

Sauerbeck D., 1989. Der Transfer von Schwermetallen in die Pflanze. Beurteilung von SM-Kontaminationen im Boden. Dechema [Hrsg. von D. Behrens, J. Wiesner]. Frankfurt/Main. 281–317.

Stählin A., 1969. Grünfutter und Heu. Handbuch der Futtermittel. Wyd Paul Parey. Hamburg – Berlin. 1, 1–177.

Szymańska M., Matraszek R., Świąder A., 1997. Zaburzenia procesów w korzeniu pod wpływem niklu na przykładzie Sinapis alba. Materiały 2 Ogólnopolskiej konferencji Zastosowanie kultur in vitro w fizjologii roślin. Zakład Fizjologii Roślin im. Franciszka Górskiego PAN, Kraków. 227–232.

Terelak H., Piotrowska M., Motowicka-Terelak T., Stuczyński T., Budzyńska T., 1995. Zawartość metali ciężkich i siarki w glebach użytków rolnych Polski oraz ich zanieczyszczenie tymi składnikami. Zesz. Probl. Post. Nauk Roln. 418, 45–60.

Terelak H., Piotrowska M., 1997. Nikiel w glebach Polski. Zesz. Probl. Post. Nauk Roln. 448, 317–323.

Vergnano O., 1953. Action of nickel on plants in serpentinite soils. Nuovo Giron. Botan. Ital. 60, 109–183.

WHO, 1972. Evaluation of certain food additives and contaminants. Geneva.

WHO, 1989. Evaluation of certain food additives and contaminants (Thirty-third Report of the Joint FAO/WHO Export Committee on Food Additives). Tech. Rep. WHO. Geneva.

WPŁYW NIKLU NA PLONOWANIE I SKŁAD MINERALNY WYBRANYCH WARZYW

Streszczenie. W trzyletnim doświadczeniu wazonowym badano wpływ niklu na plonowanie i skład mineralny części użytkowych (zawartość K, Ca, Mg, P, Fe i Ni) liści sałaty i szpinaku oraz owoców cukinii i fasoli. Doświadczenie zróżnicowano pod względem zawartości niklu ($NiSO_4 \cdot 7H_2O$), wprowadzając: 0 (kontrola); 10; 40 i 60 mg $Ni \cdot kg^{-1}$ piasku, uwzględniając równocześnie różne wymagania badanych roślin. Uzyskane wyniki badań wskazują, że już najniższa zastosowana w eksperymencie dawka niklu (10 $mg \cdot kg^{-1}$ podłoża) spowodowała istotny spadek plonu części użytkowych sałaty, szpinaku, cukinii i fasoli. Dalsze zwiększanie zawartości niklu w podłożu (40–60 $mg \cdot kg^{-1}$) pogłębiało spadek plonu liści sałaty i szpinaku.

W takich warunkach z uwagi na nieprawidłowy rozwój generatywny nie uzyskano plonu generatywnego cukinii i fasoli. Nikiel w ilości 10 $mg \cdot kg^{-1}$ podłoża wpłynął na istotny wzrost koncentracji potasu w liściach sałaty i fosforu w liściach szpinaku oraz spadek koncentracji fosforu i potasu w owocach cukinii i fasoli, powodując jednocześnie istotny spadek zawartości magnezu w owocach cukinii i istotny wzrost zawartości tego makroelementu w owocach fasoli. Zwiększenie dawki niklu w podłożu jeszcze bardziej różnicowało zmiany w składzie mineralnym roślin. Nikiel w ilości 10 $mg \cdot kg^{-1}$ podłoża wpłynął na istotny wzrost zawartości żelaza w liściach szpinaku, owocach cukinii i strąkach fasoli, a obniżał zawartość Fe w biomasie sałaty. Zwiększone dawki niklu istotnie obniżały koncentrację żelaza w organach konsumpcyjnych badanych gatunków warzyw. Wzrastające ilości niklu w podłożu wpłynęły na sukcesywne zwiększenie zawartości tego metalu w organach konsumpcyjnych badanych gatunków warzyw.

Słowa kluczowe: sałata, szpinak, cukinia, fasola, koncentracja K, Ca, Mg, P, Fe, Ni

Renata Matraszek, Maria Szymańska, Małgorzata Wróblewska, Department of Plant Physiology, Agricultural University in Lublin, 15 Akademicka Street, 20-950 Lublin, Poland