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CADMIUM AND NICKEL CONTENTS IN *HELIANTHUS TUBEROSUS* L. TUBERS

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A b s t r a c t. This study was based on tuber samples from the field experiment in 1996-1998 on weak loamy sand soil in a system of randomised sub-blocks. The experimental factors were: ways of nursery and varieties (Swojecka, Kulista Czerwona IHAR, Kulista Biała IHAR). Herbicide application elevated both cadmium and nickel contents in *Helianthus* tubers as compared to control. Tubers of Swojecka Czerwona cv. were characterised by the lowest accumulation of cadmium and nickel, those of Kulista Czerwona IHAR cv. by the highest content of nickel, and those of Kulista Biała IHAR by the highest level of cadmium.

K e y w o r d s: cadmium, nickel, Jerusalem artichoke, herbicides.

INTRODUCTION

Heavy metals including cadmium and nickel are on the list of 10 primary environment pollutants in Poland. Opinions upon the biological role of nickel in a human organism differ. It is supposed that the element disturbs the haemoglobin synthesis. Nickel is absorbed from the digestive tract and does not show the accumulation properties. However, it can invoke developmental distortions [21]. Environmental pollution with cadmium originates from chimney dust, smoke, sewage, industrial waste, metallurgy, carbon and plastics combustion, as well as transportation, because tyre rubber and lubricants contain cadmium. Almost 1/3 of the cadmium amount is emitted into the environment. Most cadmium emitted into the atmosphere is accumulated in soil and water whence it is taken by plants [6]. On agricultural areas in Poland, cadmium content in the soil amounts to 0.02-0.40 mg kg^{-1} [2,11]. About half of the total cadmium quantity is introduced into the soil with phosphorus fertilizers. Fertilization with industrial wastes, sewage sludge of unknown composition and application of high rates of pesticides also sometimes contributes to a greatly increased concentration of cadmium in soil [2,3]. The toxic action of cadmium is associated with its inhibitive influence on enzyme activity, but elements occurring in food also play a role. There are clear inter-species differences regarding the intensity of heavy metal intake by plants. Some plants such as flax, yarrow, St-John's-wort, lettuce or celery selectively uptake cadmium. Moreover, there are also differences in relation to a particular plants organs. In general, more heavy metals are found in roots and tubers than in green parts [12,21]. Baryłko-Pikielna and Tyszkiewicz [1] proved that the amount of PWTI ingested by humans with food per week is 40% of the norm for cadmium in Poland. In their opinion, potato tubers and vegetables (50%), then meat and poultry (14%) are the main source of cadmium. Therefore, the need for monitoring foodstuffs for metal pollution is necessary.

Due to the very high nutritional, taste, dietetic and medical value of *Helianthus tuberosus* L. tubers, herbicide application in its cultivation can contribute to a lowering of the nutritional and medical value. Thus, choosing nursery operations, which are lower in heavy metal content, is advisable. Therefore, the aim of studies was to estimate the variability of cadmium and nickel contents in tubers of the species under conditions of different nursery operations.

METHODS AND MATERIALS

Studies were based on tuber samples from a field experiment carried out in 1996-1998 on a soil of light loamy sand type. Cadmium content in the soil was 0.031 mg kg^{-1} and that of nickel 0.308 mg kg^{-1}. The experiment was set in a system of randomised sub-blocks in three repetitions. The experimental design included: 5 plantation nursery techniques (chemical with Linurex 50 WP applied at 1.5 kg ha^{-1} rate; Afalon 50 WP + Bladex 500 SC - 1.5 + 1.5 l ha^{-1}; applying herbicide Azogard 50 WP - 2 kg ha^{-1}; Afalon 50 WP + Command 480 EC - 1 l + 0.2 kg ha^{-1}; mechanical one) and 3 *Helianthus tuberosus* L. varieties (Swojecka, Kulista Czerwona IHAR, Kulista Biała IHAR). Mineral and organic fertilization was applied at constant rate (100 kg N, 100 kg P_2O_5, 150 kg K_2O, 250 dt ha^{-1} of manure). Among herbicides used, Azogard 50 WP is in IV toxicity class (LD_{50} 3150-3750). Prometrine is its active substance. Bladex 50 WP is in III toxicity class (LD_{50} 182). Cyanazine is its active substance. Both herbicides are from triazine group. Linurex 50 WP and Afalon 50 WP are urea derivative group (LD_{50} 400). Linurone is their active substance. Command 480 EC is a herbicide from different chemical groups (IV toxicity class, LD_{50} 1369-2077). Clomazone is its active substance [24].

Tubers were set every spring at 62.5 · 40 cm intervals. Samples of 50 tubers from every combination and every repetition were taken for chemical analyses in autumn during the harvest. Cadmium and nickel contents in tubers and soil were determined by means of AAS technique using AAS-3 apparatus (Carl Zeiss-Jena). Results obtained are burdened with spectrophotometry analysis errors (±5%). They were statistically elaborated using variance analysis. Significance of variability sources was calculated using the Fischer-Snedecor's F test. Tukey's test was helpful in estimating the difference significance.

The weather was changeable during the experiment. The years 1996 and 1998 were average as regarding to precipitations, and 1997 was an extremely wet one.

RESULTS

Content of cadmium in tubers of *Helianthus tuberosus* L. varieties was high, because it oscillated around 0.085 mg kg^{-1} DM at its limited level according to Polish Standards 0.05 mg kg^{-1} DM at dry matter content not much than 20% [26] for air-dried foodstuff (Table 1).

Table 1. The influence of herbicides on cadmium content in *Helianthus tuberosus* tubers

Experimental factors		Years 1996	1997	1998	Mean
*Herbicides	A	0.100	0.082	0.090	0.091
	B	0.097	0.080	0.090	0.089
	C	0.095	0.079	0.087	0.087
	D	0.093	0.077	0.084	0.084
	E	0.084	0.067	0.075	0.075
	LSDα≤0.05		n**		0.004
Helianthus varieties	Kulista Biała IHAR	0.106	0.082	0.092	0.093
	Kulista Czerwona IHAR	0.095	0.076	0.087	0.086
	Swojecka Czerwona	0.081	0.072	0.076	0.077
	LSDα≤0.05		n		0.002
Mean		0.094	0.077	0.085	0.085
LSDα≤0.05			0.002		

*A - Linurex 50 WP; B - Afalon 50 WP + Bladex 50 WP; C - Azogard 50 WP; D - Afalon 50 WP + Command 480 EC; E - control object; n** - not significant at α≤0.05.

All chemical nursery technique types caused an increase of cadmium concentration in *Helianthus tuberosus* L. tubers in relation to control object without herbicides, but objects with Afalon 50 WP + Command 480 EC contained its lowest level, and those with Linurex 50 WP - the highest.

Genetic properties of examined varieties determined the cadmium accumulation in *Helianthus tuberosus* L. tubers. Among all studied varieties, Swojecka Czerwona cv. was characterised by the poorest susceptibility to cadmium accumulation, Kulista Biała IHAR cv. - the strongest.

Regardless of the experimental factors, conditions of examinations significantly modified the element level in *Helianthus tuberosus* L. tubers. In 1997 with large rainfall amounts during vegetation period, plants accumulated less cadmium than in 1996 and 1998 with small rainfall quantities in relation to a many-year mean.

Nickel content in *Helianthus tuberosus* L. tubers oscillated around 0.509 mg kg^{-1}. All experimental factors modified its concentration in tubers (Table 2).

Table 2. The influence of herbicides on nickel content in *Helianthus tuberosus* tubers (mg kg^{-1})

Experimental factors		Years			Mean
		1996	1997	1998	
*Herbicides	A	0.693	0.397	0.497	0.529
	B	0.697	0.397	0.493	0.526
	C	0.670	0.407	0.500	0.526
	D	0.650	0.377	0.473	0.500
	E	0.600	0.353	0.447	0.467
	LSD$\alpha\leq$0.05		0.030		0.020
Helianthus varieties	Kulista Biała IHAR	0.552	0.366	0.442	0.453
	Kulista Czerwona IHAR	0.804	0.418	0.514	0.579
	Swojecka Czerwona	0.630	0.368	0.490	0.496
	LSD$\alpha\leq$0.05		n**		0.012
	Mean	0.662	0.384	0.482	0.509
	LSD$\alpha\leq$0.05		0.012		

*A - Linurex 50 WP; B - Afalon 50 WP + Bladex 50 WP; C - Azogard 50 WP; D - Afalon 50 WP + Command 480 EC; E - control object; n** - not significant et $\alpha\leq0.05$.

Among types of nursery applied, mechanical weed control appeared to be the safest as regarding to nickel content in tubers. Afalon 50 WP + Command 480 EC applied were the most efficient among chemical ways of nursery.

The genetic properties of the varieties under study, regardless of other factors, differentiated the element content in *Helianthus tuberosus* L. tubers. Kulista Czerwona

IHAR cv. was characterised by the strongest susceptibility to nickel accumulation in tubers, Kulista Biała IHAR cv. - the poorest.

Varieties examined were characterised by different reaction towards the herbicides applied in mechanical nursery operations. Kulista Biała IHAR cv. appeared to be the most sensible to Azogard 50 WP, Kulista Czerwona IHAR cv. - to Linurex 50 WP, and Swojecka Czerwona cv. - to Afalon 50 WP + Bladex 50 WP combination (Fig. 1).

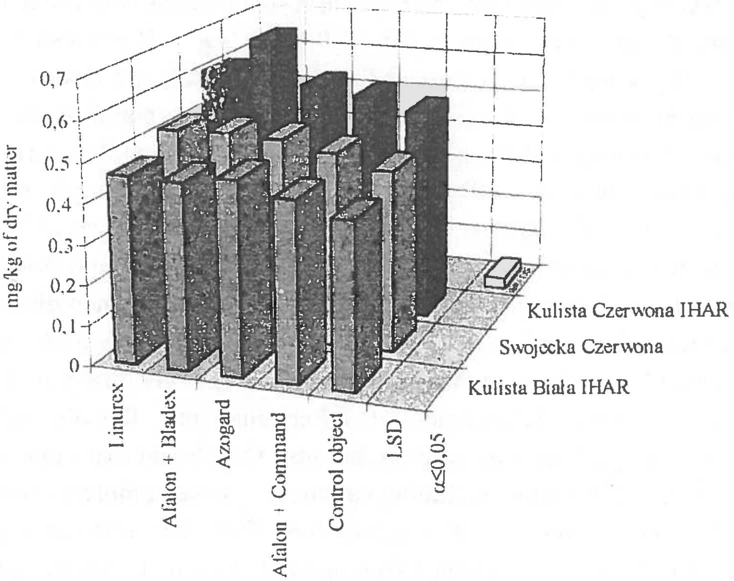

Fig. 1. The influence of varieties and herbicides on nickel content in *Helianthus tuberosus* tubers.

However, nickel accumulation in tubers mostly depended on weather conditions during the course of the experiment (Table 2). Its lowest concentration in *Helianthus tuberosus* L. tubers was found in 1997, which was almost two times smaller than in 1996 with the least amount of rainfall during vegetation period.

DISCUSSION

Mean cadmium content in *Helianthus tuberosus* L. tubers was about 0.085 mg kg^{-1} DM. Such high cadmium level in the species tubers is confirmed by research of Krełowska-Kulas [12], Omieljaniuk *et al.* [16], and Śmigiel *et al.* [23]. From the point of view of posing a threat to the human population, the high concentration of cadmium in *Helianthus* tuberosus L. tubers under study creates great anxiety.

In the opinion of Brüggemann *et al.* [3], and Olsson and Roslund [15], cadmium is taken up by the plants root system and uniformly distributed in a tuber. Olsson and Roslund [15] blamed the increase of soil, water and air pollution with the element of increased cadmium content in plants. Burton [4], and Kopeć [11] found no correlation between nickel and cadmium contents in soil and in plants. In their opinion, the cadmium content mainly depends on soil pH and aluminium concentration. Low soil pH and less organic matter favour cadmium intake by plants. Burton [4] states that only in crops harvested in areas with great heavy metal pollution, it can achieve the level of 0.1 mg kg^{-1}. Ruszkowska and Wojciechowska-Wyskupajtys [17] proved that heavy metals act destructively on a plants organism under conditions of their excessive concentration in nutritional environment. Physiological functions become more disturbed than structure anatomy or metabolic processes. Photosynthetic system is particularly sensitive towards heavy metal influence. At first, Celvin's cycle is the target of heavy metal toxic action, which leads to excessive accumulation of ATP and NADP, and in consequence, to inhibition of photosystem II. The reasons for such disturbances in the plant's metabolism can be as follows: direct inhibition of activity of enzymes engaged in the plant's photosynthesis, or interaction between heavy metals and invoking the secondary deficiencies of other elements. Results obtained by Omieljaniuk *et al.* [16] are encouraging, because they found that vitamin C forms a complex with heavy metals including cadmium. Those complexes are absorbed or excreted in other ways as metals themselves. Therefore, one can suppose that the high level of vitamin C, of which *Helianthus tuberosus* L. tubers contain more than 20 mg% of fresh matter, in a diet, can cause the elevated excretion of cations with urine including heavy metals.

Nickel is a metal whose level has not hitherto been limited by Health Ministry standards for foodstuffs. However, there are projects of critical values of the metal contents in plants recalculated onto air-dried matter and elaborated by Kabata-Pendias *et al.* [8]. For root plants, the proposed limiting value for nickel in those authors opinion, for plants with consumption purposes should amount to 5 mg kg^{-1} and for fodder 8 mg kg^{-1} of fresh matter. Mikos-Bielak *et al.* [14] studying nickel content in tubers of different potato varieties found that the element concentration ranged from 0.025 up to 0.132 mg kg^{-1} DM, and they proved that a greater accumulation of nickel occurred in outer parts of plant (peeling) than in parenchyma. Those results can be partially equalled to *Helianthus tuberosus* L.

Application of herbicides of different groups caused the increase of nickel and cadmium accumulation in *Helianthus tuberosus* L. tubers. In the opinion of Hess [7], Gauvrit [5], and Makarska [13], the application of triazine, urea and other groups herbicides can contribute to modification in the plants growth and development, and in consequence to changes of technological value of raw material. Herbicides can transfer from leaves and stems to fruits, seeds and tubers and accumulating there, can change the physiological, biochemical and consumption properties [5,10]. Due to herbicides, durable or transient changes of crop structure can occur. Hess [7], Gauvrit [5], and Kirkwood [10] suggest that durable morphological changes lead to decrease of yields and their quality in varieties sensitive towards different preparation influence. In the opinion of Scalla [22], Hess [7] and Makarska [13], those changes are the result of disturbances of the physiological and biochemical processes, especially differentiation of photosynthesis intensity and content of biologically active substances.

Existing dependence between weather conditions and *Helianthus tuberosus* L. sensitivity to herbicides points that mineral composition of tubers, mostly determined by genetic factors and habitat, can be changed after application of herbicides under unfavourable weather conditions. Such findings relating to cereals, were confirmed by Makarska [13]. In the opinion of Vanova and Benada [25], low temperatures and small rainfall can create worse conditions in the soil for herbicide decomposition and widen their phytotoxicity.

The dependence of nickel and cadmium concentrations on genetic properties of varieties under study was also confirmed by Keller and Baumgartner [9] and Sawicka [18,19].

From research of Keller and Baumgartner [9], Makarska [13] and Sawicka [20] it follows that the inhibitive action of herbicides can appear causing the decreasing or increasing tendencies of some chemical components under unfavourable weather conditions, and the size of changes depends on the genetic susceptibility of a given variety to a given preparation.

Data pointing to differentiated reaction of *Helianthus tuberosus* L. varieties towards new herbicides are the premise to conduct further, complex cognitive and practical research not only upon the size, but also the quality of the yield.

CONCLUSIONS

1. Chemical nursery of plants using herbicides contributed to the increase of cadmium and nickel concentrations in *Helianthus tuberosus* L. tubers as compared to mechanical nursery operations without herbicides; the most cadmium and nickel amounts in tubers were found in objects with Linurex 50 WP application.

2. Genetic properties of varieties under study determined the nickel and cadmium accumulation in *Helianthus tuberosus* L. tubers; Kulista Biała IHAR cv. accumulated the most cadmium in tubers, and Kulista Czerwona IHAR cv. accumulated the most nickel quantities.

3. Plants accumulated less toxic elements in tubers in years with an elevated precipitation sum in relation to many-year average, than in years with their deficiency.

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