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POLLUTION OF EARLY POTATO VARIETY TUBERS WITH LEAD AND STRONTIUM IN EASTERN POLESIE

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A b s t r a c t. Trace elements contents analyses were made in tuber samples collected from the field experiment in 1996-1998 in Experimental Station, Parczew, on weak loamy sand soil. The following experimental factors were taken into account: their cultivation technologies; two potato varieties (Aster and Drop). The lead content in very early potato tubers appeared to be higher than the permissible one in all study years. The highest lead content was found in young tubers harvested on 60th day after setting. Along with the delay of harvest, the lead level tended to be lower. Tubers harvested on the 75th day after setting accumulated the most strontium, those physiologically matured had the lowest level of this element. All types of coverage applied in the study contributed to the increase of lead content in tubers of very early potato varieties as compared to traditional cultivation. Neither cultivation technologies nor variety features modified the strontium accumulation in tubers.

K e y w o r d s: lead, strontium, potatoes, varieties, cultivation technology, harvest date.

INTRODUCTION

The quality of potato tubers in a view of some bio-element contents is an important problem due to high level of their consumption in Poland, especially in middle-eastern region where the plant is over 20% of cultivation structure. In turn, pollution of foodstuffs with some trace elements causes many diseases in animals and even in humans. During the vegetation period, habitat and agrotechnical factors influence the chemical composition of tubers. Foodstuffs are a main source of lead introduced into the organism. About 80-90% of the metal amount is taken through the digestive tract, and 10-20% through the respiratory system [8,9,11,13]. Toxic action of lead manifests as disturbances of heme synthesis necessary for haemoglobin creation. Damages of central nervous system can occur particularly in children, which can manifest as hyper-excitability, weakened ability for learning, movement ataxia, lack of feeling, difficulties in concentration, lowered intelligence. Inorganic lead has its toxic action towards peripheral nervous system. Kidney injuries can also arise, functional disturbances with handicaps of reciprocal imbibition, as well as nephropatia with symptoms of irreversible kidney insufficiency. Children of pre-school age, who can have neurophysiological disturbance symptoms due to relatively low Pb concentrations, are especially at risk [5].

Strontium is emitted into the atmosphere by non-ferrous metal works, glass factories, pharmaceutical works and dye-houses. Two isotopes are formed due to nuclear reactions: ^{89}Sr and ^{90}Sr. Strontium content in the soil depends on its occurrence in a matrix and amounts from 5 to 1000 ppm. Its level in plants is within 0.4-1500 ppm DM depending on its concentration in the soil. Strontium accumulates mainly in old leaves, roots and tubers of plants. It transfers into the plants both from the air and soil [6]. The element is accumulated mostly in bones and soft tissues (brain) in humans and animals. Strontium is necessary for proper development, and its absence reduces the growth and disturbs the liming process in teeth and bones. Toxic concentration of strontium in animals organisms is seldom recorded and its excess causes distortion of phosphorus, copper and cobalt metabolism. Radioactive isotope ^{90}Sr concentrated in plants (to which it is introduced from the soil), is a potential threat to animal and human organisms. It invokes chromosome aberrations and is the cause of bone system cancer [2,5,12].

The quantity of metals taken by humans with the food during the week is governed by PTWI norm (Provisional Tolerable Weekly Intake). Baryłko-Pikielna and Tyszkiewicz [1] found that for lead such amount is 20% of PTWI in Poland. In their opinion; cereal and vegetable products are main daily sources of lead taken by people (about 65%). That is why, there is a need to monitor the pollution of foodstuffs with metals. Therefore, the aim of the present study was to estimate the influence of varieties and cultivation technologies on lead and strontium contents in potato tubers harvested at different stages of maturity.

MATERIAL AND METHODS

Results were based on a field experiment conducted in The Field Experimental Station, Parczew, on light loamy sand soil in 1996-1998. The soil was characterised by high level of available phosphorus, very high in potassium, very low in magnesium, low in copper and iron, moderate in manganese and high in zinc. Heavy metal contents in the soil amounted as follows: Pb - 30 mg kg^{-1}; Sr - 0.1 mg kg^{-1} of soil, which can be accepted as middle polluted soil. Fifty tubers from 3 repetitions of every combination were taken for laboratory analyses. Two items were the experimental factors: 1 - cultivation technologies: a) using polypropylene fibre as a coverage, b) traditional cultivation - as a control; 2 - potato varieties - very early Aster and Drop. Mineral and organic fertilization was constant: 80 kg N, 80 kg P_2O_5, 120 kg K_2O and 250 dt ha^{-1} of manure. Tubers of elite class were the setting materials. Potatoes were cultivated according to modern agrotechnics recommendations. Tuber harvest was done at three dates: 60, 75 days after setting and just after maturity. Lead and strontium contents in tubers and soil were determined by means of AAS technique using AAS-3 apparatus (Carl Zeiss-Jena). Results obtained were burdened with spectrophotometry analysis errors (±5%). They were statistically elaborated using variance analysis. Significance of variability sources was calculated using Fischer-Snedecor's F test. Tukey's test was helpful in estimating the difference significance. Years 1996 and 1998 were average both with regard to precipitation sum and air temperature, 1997 was extremely wet and cold.

RESULTS

Lead content in potato tubers was at the level of 0.976 mg kg^{-1} DM (Table 1) and it was much higher than limiting value for potato [15].

All types of coverage in early potato variety cultivation contributed to increasing the lead concentration in tubers as compared to traditional technology (Table 1).

Tubers cultivated under double cover made of fibre and polyethylene contained the highest lead content. The influence of cultivation technology on the element content in tubers depended on weather conditions during the experiment and harvest term. In wet years, the least amounts of lead were found in tubers cultivated under double cover made of fibre and polyethylene, but in average 1996 year - under fibre cover.

Physiological maturity also determined the lead accumulation in tubers (Tables 1, 2). The highest lead content was found in young tubers harvested on the 60th day after setting. The element concentration in potato tubers decreased along with the delay of harvest date. Dependence of lead accumulation on physiological state of tubers was only confirmed for cv. Aster. For cv. Drop, significant decrease of lead content in tubers was observed only in physiologically matured tubers, in relation to non-matured ones.

Lead accumulation in non-matured tubers harvested at 60th and 75th day after setting appeared to be the highest in cultivation with perforated polyethylene

Table 1. Lead contents in mg/kg of dry matter of potato tubers

Experimental factors		Years			Mean
		1996	1997	1998	
Technology	A	1.234	0.816	0.806	0.952
	B	1.268	0.859	0.848	0.992
	C	1.226	0.841	0.833	0.967
	D	1.379	0.813	0.793	0.995
	LSDα≤0.05		n**		0.006
Varieties	Aster	1.271	0.829	0.829	0.973
	Drop	1.283	0.836	0.820	0.980
	LSDα≤0.05		0.010		0.002
Harvest time	I	1.367	0.807	0.831	1.008
	II	1.356	0.840	0.799	0.998
	III	1.088	0.851	0.830	0.923
			n		0.004
Mean		1.277	0.832	0.820	0.976
LSDα≤0.05			0.002		

*A - traditional; B - with polyethylene sheeting; C - with polypropylene sheeting; D - with polypropylene and polyethylene sheeting; n** - not significant at α≤0.05.

Table 2. Lead contents in mg/kg of dry matter of potato tubers

Experimental factors		Years			Mean
		1996	1997	1998	
Technology	A	0.969	1.010	0.878	0.952
	B	1.064	1.057	0.854	0.992
	C	1.056	0.959	0.886	0.967
	D	0.935	0.964	1.082	0.995
	LSDα≤0.05		n**		0.006
Varieties	Aster	1.018	0.997	0.905	0.973
	Drop	0.996	0.998	0.945	0.980
	LSDα≤0.05		0.012		n
Mean		1.008	0.998	0.923	0.976
LSDα≤0.05			0.004		

*A - traditional; B - with polyethylene sheeting; C - with polypropylene sheeting; D - with polypropylene and polyethylene sheeting; n** - not significant at α≤0.05.

cover, but in matured ones - under double cover made of fibre and polyethylene foil (Table 1).

Varieties under study significantly differed as regarding to lead content in tubers. Variety Drop was characterised by higher concentration of the element than cv. Aster (Tables 1 and 2). Lead accumulation in tubers depended on reaction of variety towards the edaphic conditions during experiment. Significant differentiation of tubers, in a view of the lead content, was observed only in 1996 and 1997 with extreme course of weather conditions. Lead content variability also depended on physiological maturity of tubers during the harvest. Difference between studied varieties was significant only for harvest at 60th days after setting and just after maturation. In the earliest term of the harvest, cv. Aster accumulated the most of lead, cv. Drop - after maturation.

Lead level in tubers, regardless of other experimental factors, was modified by weather conditions (Table 1). In 1997 and 1998 with very high and quite high rainfalls during the vegetation period, lead content in tubers was significantly lower than in 1996 with sunny dry weather. Varied concentration of lead in the soil could also contribute to its different content in potato tubers.

Strontium content in tubers oscillated about 0.079 mg/kg DM, on average (Tables 3 and 4). Strontium is a metal whose level is not limited for foodstuffs by the Health Ministry yet. Tubers on the 90th day after setting contained the most strontium, those after maturation the least (Table 3).

Coverage applied in potato cultivation contributed to significant increase of the metal in relation to traditional technology. Tubers cultivated under double cover made from fibre and foil contained the highest amounts of strontium, those cultivated using perforated polyethylene foil only the lowest. The element concentration in tubers cultivated under fibre and foil coverage did not differ significantly (Table 3).

Accumulation of strontium in potato tubers also depended on the interaction of cultivation technology and harvest term. Most strontium was found in cultivation under polyethylene foil cover on the 60th day after setting; under double cover made from fibre and foil on the 75th day after setting; and in objects under fibre just after the maturation (Table 4).

Varieties under study differed with the strontium accumulation level during the entire experiment (Table 3). In 1996, cv. Aster was characterised by higher concentration of the element, but in 1997 and 1998 with a large amount of rainfall during vegetation period - cv. Drop.

However, the weather conditions in experimental years had the determining effect on strontium concentration in tubers (Table 3). Almost two times higher

Table 3. Strontium contents in mg/kg of dry matter of potato tubers

Experimental factors		Years			Mean
		1996	1997	1998	
*Technology	A	0.110	0.058	0.057	0.075
	B	0.104	0.065	0.065	0.078
	C	0.111	0.066	0.067	0.081
	D	0.113	0.067	0.067	0.082
LSDα≤0.05			n**		0.002
Varieties	Aster	0.112	0.061	0.061	0.078
	Drop	0.107	0.066	0.067	0.080
LSDα≤0.05			0.002		n*
Harvest time	I	0.108	0.065	0.061	0.078
	II	0.113	0.071	0.073	0.086
	III	0.107	0.055	0.057	0.073
			n		0.001
Mean		0.110	0.064	0.820	0.079
LSDα≤0.05			0.001		

*A - traditional; B - with polyethylene sheeting; C - with polypropylene sheeting; D - with polypropylene and polyethylene sheeting; n** - not significant at α≤0.05.

Table 4. Strontium contents in mg/kg of dry matter of potato tubers

Experimental factors		Harvest date		
		I	II	III
*Technology	A	0.076	0.076	0.073
	B	0.091	0.073	0.070
	C	0.072	0.095	0.077
	D	0.071	0.103	0.073
LSDα≤0.05		0.002		
Varieties	Aster	0.080	0.082	0.073
	Drop	0.075	0.091	0.074
LSDα≤0.05			n*	

*A - traditional; B - with polyethylene sheeting; C - with polypropylene sheeting; D - with polypropylene and polyethylene sheeting; n** - not significant at α≤0.05.

strontium content was observed in 1996 than in 1997 and 1998 with high precipitations during the vegetation period.

DISCUSSION

On average, lead concentration in early potato tubers exceeded the limits (0.25 mg kg^{-1} DM). In opinion of Kabata-Pendias [6]; lead intake by plants from the soil depends on its acidity, organic matter and phosphorus contents. Lead transfer into plants increases along with the increase of soil acidity. However, humus content increase reduces the lead intake. Soil where experiments were carried out, was little acidic, and humus content was low. Thus, one can suppose that it made good conditions for lead intake by plants.

Cultivation technologies applying all types of coverage for early potato varieties contributed to the increase of lead content in tubers as compared with traditional cultivation; tubers cultivated under double cover made from fibre and polyethylene foil were characterised by the highest lead level. The negative effect of cultivation technology under coverage on these elements contents should be mostly assigned to significant shift of vegetation toward spring, which is predominantly associated with the rate of physiological ageing of maternal tubers.

The highest lead content was observed in young potato tubers i.e. harvested on the 60th day after setting. Those results were confirmed by earlier studies of Sawicka [11]. Brüggemann *et al.* [2] state that freshly harvested tubers contained little amounts of lead for its level increases during storage due to atmospheric contamination (dust, exhausting gases, atmospheric precipitations).

The influence of weather conditions on heavy metal accumulation in potato tubers were confirmed by research of Keller and Baumgartner [7], Yildrim and Caliscan [14], Prośba-Białczyk [10] and Sawicka [11]. In opinion of Bondar [4], radioactive strontium gets into the tubers in minimum quantities, even at relatively high soil pollution with it. He states that contents of radioisotopes in tubers was much lower than in fodder, fruits, vegetables, cereals and milk after the damage in Chernobyl and their activity was within the normal level. In the opinion of Brüggemann and Ocker [2], most traces of isotopes are removed during peeling and the following processing of potatoes.

Lead and strontium concentrations in potato tubers were determined by genetic properties of studied varieties. Dependence of trace element contents on genetic features were confirmed by Keller and Baumgartner [7], Brüggemann *et al.*

[2], Yildrim and Caliscan [14], Kerłowska-Kulas [8], Prośba-Białczyk [10], Sawicka [11].

The influence of vegetation conditions on strontium content in tubers was confirmed by research of Brüggemann and Ocker [3]. It should be supposed that little amounts of humus and flooded fraction in sandy soil under the present experiment, determined a slight action of potassium ions in heavy metals desorption.

The obtaining of plant raw material free from heavy metals is impossible, thus the legal requirements limiting their content must be strictly complied with by farmers, foodstuffs and pharmaceuticals producers, and their concentrations should be monitored by PIH and Pharmaceutical Services. Farmers should be trained and their raw materials must fulfil requirements of Polish Norms. Cultivation must not be situated near roads with intensive traffic nor large industrial works. Changes have been observed for several years both in Poland and at our neighbours, make us review existing production methods, preparing for trade and export of potatoes. Producers of this raw material from countries trying to join the EU will have to adapt to the demands of their markets. Moreover, the pressure of consumers demanding healthy and safe foodstuffs demands that this product be under more precise control by hygienic services at all stages of trade turnover.

CONCLUSIONS

1. The highest lead content was found in young tubers harvested on the 60th day after setting, the highest strontium level was observed in tubers harvested on the 75th day after setting. Tubers just after maturation contained the least amounts of both elements.

2. Coverage applied in potato tuber cultivation contributed to lead and strontium concentration increase as compared to traditional technology. Cultivation using polyethylene foil cover appeared to be the safest regarding to strontium content, and that with fibre application regarding to lead level.

3. Variety properties determined the lead accumulation in tubers. Drop cv. showed higher ability for lead accumulation than Aster cv.

4. Aster cv. was characterised by higher contamination with strontium under deficiency of rainfall conditions and Drop cv. at the excess of it.

5. In years with an elevated rainfall amount, in relation to a many-year mean, plants accumulated less toxic elements in tubers of early potato varieties.

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