EXPLORING POSSIBILITIES OF CULTIVATION A UNPOLLUTED PLANT PRODUCE IN Pb AND Cd CONTAMINATED SITES

ВЪЗМОЖНОСТИ ЗА ПОЛУЧАВАНЕ НА ЧИСТА ПРОДУКЦИЯ ОТ КАРТОФИ В РАЙОНИ НА ЗАМЪРСЯВАНЕ С Pb и Cd

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ABSTRACT

The control of heavy metals in such way that soil function and product quality are not impeded is a prerequisite to sustainable agriculture. Growing anthropogenic fluxes of toxic heavy metals in agro-ecosystems affect on purity of farm products and soil fertility.

In the article we describe a field experiment – cultivation of potatoes on soil with a medium level of pollution / Zn, Cu, Pb, Cd etc/. We studied the most toxic of them – Pb and Cd; as well as the possibilities for reducing their phytoavailability and accumulation in potatoes tubers, applying soil amendments.

KEY WORDS: lead, cadmium, potato, soil contamination, remediation

РЕЗЮМЕ

Контролът върху тежките метали, осъществяван така, че да не се нарушава почвената функционалност и качеството на продукцията, е важно условие за развитието на устойчиво земеделие. Все по-нарастващите техногенни потоци от токсични тежки метали в агроекосистемите, поставят с все по-голяма острота въпроса за чистотата на земеделската продукция и почвеното плодородие.

В настоящата публикация са проучени възможностите за отглеждане на картофи върху почви, със средно ниво на полиметално замърсяване с цинк (Zn), мед (Cu), олово (Pb), кадмий (Cd) и др. Обект на проучването са най-токсичните от тях – Pb и Cd, както и способи за намаляване на преноса им в растенията и натрупване в клубените на картофите, чрез използване на различни почвени добавки.

КЛЮЧОВИ ДУМИ: олово, кадмий, картофи, замърсяван на почвата, ремедиация

ПОДРОБНО РЕЗЮМЕ

Почвеното замърсяване с тежки метали е глобален проблем. В Р България преобладаващата част от замърсените почви са контаминирани с Pb и Cd [13]. Тези метали, освен че са най-масовите замърсители, се отличават с високата си токсичност за хората, животните и растенията. Наред с токсичността си Pb и Cd проявяват висока способност за биодостъпност и биокумулативност в растенията, отглеждани за хранителни нужди. Картофите са едни от културните растенията с висок биокумулативен потенциал, спрямо тежките метали[6].

В това изследване проучихме способността на картофите да отлагат Pb и Cd в клубените си, при отглеждане в район на индустриално замърсяване – в близост до комбинат за добив на цветни метали. Втората задача, която си поставихме беше, чрез използване на подходящи добавки да постигнем инактивация на фитодостъпните форми на Pb и Cd в почвата и намаляване на натрупването им в картофените клубени.

Беше проведен полски експеримент с картофи от сорта "Агрия". Изпитахме възможностите на 4 типа почвени добавки, с различни физични и химични свойства, за имобилизация на подвижните форми на Pb и Cd в почвата, при конкретните агрометеорологични условия (Табл.3) Бяха отчетени както тоталните, така и подвижните форми на токсичните метали в почвата(Табл. №№ 1,5). Повечето от почвените добавки показаха значително намаляване на натрупването на Pb, спрямо контролния вариант. При вариант №2 се установи едновременно намаление на Pb и Cd в клубените под пределно допустимите санитарни норми. Проследен беше и физиологичния ефект от прилаганите почвени добавки върху тестовата култура(Табл. №4).

INTRODUCTION

Adverse changes in environment and ecological conditions, as result of anthropogenic impact, become more and more tangible and menacing. Soil contamination with heavy metals is a precondition for their accumulation in agricultural produce [6, 13]. The high persistence of toxic metals, their mobility and toxicity make them one of the most dangerous contaminants of the environment [2, 7]. Because of that, cultivation of unpolluted plant production in agricultural sites fouled up with toxic heavy metals becomes increasingly important [1, 12].

There are known many different methods for this purpose (soil remediation technologies): S/S remedy [10], soil enrichment with organic matter [4], physical and chemical immobilization [9], phyto- and microbial remediation [8], electrocinetics, vitrification and many others. Selecting the type of soil remediation one has take into consideration plenty of different factors: breeding plants, agromerheorological conditions, pH, type and characteristics of the soil, characteristics and levels of contaminating metals, etc.

In this studying, we aimed to investigate possibilities of some basic remediation techniques (enrichment with organic matter, testing new materials for physical and chemical immobilization of toxic metals). The first goal we put was decreasing the transfer of heavy metals from soil to plants and breeding of unpolluted plant produce. Remedy techniques we applied in this way to cause no injury of soil, normal plant development and soil fertility.

MATERIALS AND METHODS

We examined two of the most widespread and toxic polluting heavy metals – Pb and Cd. As a test plant, we chose one of most important agricultural culture – potatoes (Agria cv), known with their ability to accumulate heavy metals [11, 14]. The field experiment was carried out during 2003 on a parcel of 1 da. It was situated on 1,6 km from source of polluting / nonferrous works near Plovdiv/. Type of soil is Fluvisols, sandy loamy. Erosion and saltiness were not finding out. Some basic soil parameters

/ layer 0-30cm/ are shown in Tabl.1.

Experiment was conducted in five variants, in three reiteration every, on parcels of 20 m^2 each. Parcels were located after randomization. Remedy techniques were applied in this way to do not impede normal plant vegetation, soil microbiota and multifunctionality.

In every experimental variant / except control – № 1/ we introduced in soil different material, purposely to decrease transference of heavy metals through the chain soil-plant-plant produce.

Description of the experimental variants:

- var. N1 – untreated soil;
- var. N2 – bio mass was amended to soil in amount 4 kg/m^2;
- var. N3 – an agent / containing S^{2+}ions/ with light alkalescency($pH_{5\%}$= 7.5) was amended to soil, in amount 25 dm^3/m^2, like 0.005% solution;
- var. N4 – a material with chemisorption's characteristics was amended to soil in amount 10 kg/m^2;
- var. N5 – an acid agent / containing PO_4^{3-} ions/, with $pH_{5\%}$= 2.1, was amended to soil, like 0.16% solution, in amount 25 dm^3/m^2.

Table 1. Soil parameters of experimental site

pH -	Humus %	ES -5 -	Salts %	Mineral N mg %	P_2O_5 mg %	K_2O mg %	CO_3^{2-} %
6.87	0.82	181	0.059	0.75	5.75	35	8.5

Table 2. Heavy metal levels in soil

Табл.2. Нива на тоталните форми на тежки метали в почвата

	Pb mg/kg	Cd mg/kg	Cu mg/kg	Zn mg/kg	Mn mg/kg
Background	22	0.08	23	70	-
Variant №1-control	163	4.4	97	408	1094
Levels after amendment:					
Variant №2	166	4.6	100	412	1109
Variant №3	160	4.3	94	406	1074
Variant №4	161	4.3	95	407	1066
Variant №5	163	4.2	97	406	1080
U L	80	3	260	340	-

Soil amendments were applied 45 days before planting of the potatoes [4, 9]. Plants were cultivated acc. accepted in Bulgaria agricultural technologies for middle early production.

Soil and plant samples were collected acc. BDS 17-45.01/85. Potato tubers, before analysis were thoroughly washed up with drinking water and after that with deionized water. We analyzed total contents of heavy metals by "pseudo-total" method, acc. BDS 17.4.4.03-80. Measuring of metal quantities was accomplished by AAS. Mobile metal forms in soil were analyzed with AAS,

in 0.05 M Na_2-EDTA extract.

During the vegetation were kept under observation fenelogical indicators (acc. Instruction for fenological supervision of IHM) and biometrics (acc. Instruction for agro meteorological supervision of IHM at Bulgarian Academy of Science). We also rendered an account of agro meteorological conditions on the basis of which different indexes were determined. Physiological indices (photosynthesis speed and transpiration intensity) were measured in blossoming stage, on first intact leaf, by portable photosynthetic system LCA-4. Qualitative parameters of produced potato tubers / dry weight, vit C, starch and etc./ as well were read.

RESULTS AND DICUSSION

Background levels [acc. 2] of heavy metals in soil as the quantities before and after amendment are present in Tabl.2.

Agro meteorological conditions in vegetation period are shown in Table. 3.

Obtained physiological data are presented in Table 4.

Levels of mobile(Na2EDTA) forms of heavy metals in soil are included in Table 5.

Heavy metal content in potato tubers for different variants is presented in Table 6.

Analysis of data from Table 2 shows that soil amendments did not pollute soil additionally with heavy metals. Photosynthesis speed and transpiration intensity / Tabl.4/ are highest in Var. № 5 – because of stimulation of potato plants in consequence of strengthened phosphorus nutrition of plants in this variant.

Levels of mobile forms of heavy metals in soil / Table 5/ are:

- for Pb – highest in Var. № 3 / 135% compared to control variant/ and lowest in Var. № 4 / 83% in comparison with control variant/;
- for Cd – highest values are fixed for Var.№ 5 / 108% compared to control variant/ and lowest for var. № 4/ 75% in comparison with control variant/.

Contents of toxic heavy metals in potato tubers/ Table 6/ are:

- for Pb – highest in Var. № 5 / 106% compared to control variant/ and lowest in Var. № 4 / 53% in comparison with control variant/;

Table 3. Agro meteorological conditions during vegetation period
Табл.3. Агрометеорологични условия през вегетационния период

Indexes *	IV	V	VI	VII	VIII	IX
t (^{0}C)	11,0	19,7	24,6	25,7	26,0	18,8
R (mm)	83,8	85,6	18,6	42,2	7,9	24,8
r (%)	64	69	62	54	54	59
HTC	2,53	1,40	0,25	0,53	0,10	0,44

Table 4. Physiological parameters
Табл.4. физиологични показатели

Variant	Photosynthesis speed	Transpiration intensity
	μmol $CO_2/m^2/s$	mmol $H_2O/m^2/s$
Variant №1- control	10.11	1.72
Variant №2	10.62	1.74
Variant №3	10.60	1.73
Variant №4	10.92	1.67
Variant №5	11.49	1.84

Table 5. Levels of mobile forms of heavy metals in soil (mg/kg)
Табл.5. Нива на подвижните форми на тежките метали в почвата(mg/kg)

Variant	Pb	Cd	Zn	Cu	Mn
Variant №1- control	8.828	2.965	68.955	51.300	146.88
Variant №2	7.945	2.342	48.047	49.660	125.31
Variant №3	11.200	3.621	46.520	48.170	112.75
Variant №4	7.352	2.250	42.883	32.437	96.709
Variant №5	9.557	3.211	66.091	40.434	90.421

Table 6. Contents of heavy metals in potato tubers (mg/kg fresh weight)
Табл.6. Съдържание на тежки метали в клубените на картофите (mg/kg свежа маса)

Variant	Pb	Cd	Zn	Cu	Mn
Variant №1- control	0.595	0.0395	1.33	2.05	3.22
Variant №2	0.454	0.0225	5.78	1.73	1.72
Variant №3	0.442	0.0423	6.99	5.91	3.23
Variant №4	0.318	0.0434	7.45	4.62	6.47
Variant №5	0.632	0.0431	8.82	3.39	1.65
U L	0.5	0.03	10	10	-

- for Cd – highest values are fixed for Var.№ 4 / 193% compared to control variant/ and lowest for var. № 2/ 43% in comparison with control variant/.

DISCUSSION

1. Applied amendments do not enhance heavy metal contents in soil and do not disturb growth of potatoes, under concrete agro meteorological conditions.
2. In the presence of multimetal contamination, soil amendments decrease Pb content (toward control variant) in tubers at Variant 4, followed by Variants 2 and 3. In any of these variants, Pb is below UL.
3. Decreasing of Cd levels in potato tubers, below UL and control variant, is proved in Variant 2.
4. Independently of agro meteorological conditions at Variant 2 used amendment reduce concomitant Pb and Cd levels below UL.
5. The values of other heavy metals (Zn, Cu, and Mn) in potato tubers for all variants are under UL.

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