Relation between soil characteristics and heavy metal content in Virginia tobacco

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Abstract
The study was conducted on alluvial-meadow soils (Fluvisols), cinnamonic forest soils (Chromic Luvisols) and smolnitzi (Vertisols) with Virginia tobacco. pH, humus, total content and mobile forms of Pb, Cd, Cu and Zn in soils, as well as concentration of the elements in roots and aboveground biomass of tobacco were specified. Statistically significant dependencies between soil reaction and Cd content in leaves, stems and blossoms of Virginia tobacco were established. pH increase led to reduction of Pb, Cu and Zn concentration in plant organs but these relations were not statistically proven. The humus content influenced Pb and Cd accumulation in leaves of the three harvesting zones and of Cu in stems and blossoms. Statistically significant dependencies with varying degree of correlation were established between total Pb, Cd, Cu, Zn content, their mobile forms in soil and element concentration in plant organs (mainly in leaves) of Virginia tobacco. The obtained regression dependencies in the soil-tobacco system may be used for solving various scientific as well as scientific and practical tasks for prognostication and prevention of tobacco heavy meal contamination.

Key Words
Soil, Heavy Metals, Tobacco (Virginia)

Introduction

The heavy metal content in tobacco leaves was variable and depended on the conditions, under which tobacco was grown and mostly on the composition and properties of soils. One of the major factors influencing the element concentration in tobacco leaves was soil reaction (Adamu *et al.* 1989; Gondola and Kadar 1995). Golia *et al.* 2003 found a significant negative correlation between pH of soil and heavy metal content in oriental tobacco, while in the case of Virginia variety group, such correlation was determined only with cadmium, copper and manganese. The same authors have not found any relation between the total content of metals in soil and in leaves of oriental tobacco, Virginia and Burley. Another soil characteristic influencing the heavy metal concentration in tobacco was the humus content (Adamu *et al.* 1989). The same authors have found statistically important relations between the mobile forms of zinc, manganese, nickel and cadmium extracted from the soil by means of different extragents and their concentration in tobacco leaves. Such dependency has not been determined for lead. The purpose of this study was to provide information on the relation between pH, humus, total content and mobile forms of lead, cadmium, copper and zinc in soil, as well as the concentration of these elements in roots and aboveground biomass of Virginia tobacco.

Methods

The study was conducted in the period 2005-2007 on alluvial-meadow soils (Fluvisols), cinnamonic forest soils (Chromic Luvisols) and smolnitzi (Vertisols) with Virginia tobacco (37 soil samples). The samples were taken from depth of 0-30 cm. The following soil characteristics were determined: pH in water (1:1), humus, total content of Pb, Cd, Cu and Zn through decomposition by HF, $HClO_4$ and HNO_3 acids. A solution of 0.005M DTPA + 0.1M TEA, pH 7.3 was used for extraction of element mobile forms from soils. The preparation of plant samples (roots, stems, leaves of the three harvesting zones and blossoms) was made by means of dry ashing and dissolution in 3 M HCL. An atomic-absorptional spectrometer "Spektra AA 220" of the Australian company Varian was used for determination of heavy metal content at the following operating wavelengths: Cd – 228.8 nm, Pb - 217.0 nm, Cи - 324.8 nm, Zn – 213.9 nm.
Certified Reference Material of soil (Light Meadow Cinnamonic Soil PS-2, SOOMET № 0002 - 1999 BG, SOD №311^{a}-98) and of Virginia tobacco leaves (a Polish reference material CTA-VTL-2) was also analyzed for the verification of the accuracy of trace element determination in soil and in tobacco.
SPSS program for Windows was used for statistical data processing. A correlation-regression analysis was conducted between pH, humus content, total and mobile forms of Pb, Cd, Cu and Zn in soil, as well as the concentration of the elements in roots and aboveground biomass of Virginia tobacco.

Results

Soils

Table 1 presents pH values for the tested soils. As evident from the table, soil reaction was within the range from 5.25 to 7.73. The arithmetic mean was 6.65 – a value which stood close to the value considered optimal by Stephenson *et al.* 1987 for flue-cured tobacco. The humus content was within the range from 1.07 to 2.45 (low to medium), as most of the soils had low humus content and they were suitable for the Virginia variety group.

Table 1 Soil properties, content of Heavy metals in soil (n = 37)

Statistical index	pH	Humus %	Pb, mg/kg		Cd, mg/kg d		Cu, mg/kg		Zn, mg/kg	
			total	Mobile forms	total	Mobile forms	total	Mobile forms	total	Mobile forms
mean	6.65	1.82	19.78	3.74	0.78	0.24	62.92	4.19	95.51	2.83
Minimum	5.25	1.07	4.00	0.50	0.40	0.05	15.00	0.46	34.6	0.31
Maximum	7.73	2.45	116.00	31.60	3.00	1.44	399.20	24.28	280.00	25.26
CV, %	11.34	22.70	129.64	191.98	68.53	124.90	113.92	128.17	52.77	198.20

The total lead content in the soils varied broadly – from 4 to 116 mg/kg. According to the requirements of the Bulgarian standards lead content was above the allowable concentration in only two types of soil. These types of soil could be found close to an industrial source of contamination, which was the reason for the higher lead content. The mobile lead content also varied broadly – from 0.5 to 31.6 mg/kg. The highest values were measured in soils near the source of contamination, where the total content of the element was the highest.

The total cadmium content in soils varied from 0.4 to 3 mg/kg. All measured values were below the allowable concentration with the respective pH. Mobile cadmium in soils varied broadly from 0.05 to 1.44 mg/kg, as highest concentrations were measured in soils near an industrial source of contamination.

The total Cu content was within the range from 15 to 399.2 mg/kg. It exceeded the allowable concentration with the respective pH with one soil only. Generally speaking, the element content was higher than the state-average one, which was 30 mg/kg. The arithmetic mean reached 62.92 mg/kg. Mobile Cu content also varied in a wide range. According to MAFF classification (Mitsios *et al.* 2005) some soils which were subject of the present study, were characterized as having very large reserves of mobile copper.

With many soils the total zinc content was close to the state-average. It was higher with some soils, but it was below the allowable concentration. The mobile Zn content varied broadly and most soils had small or medium reserves.

Tobacco

Table 2 presents the values of lead concentration in plant organs of tobacco grown in all studied regions. If you trace the average element content in the separate parts of tobacco plants you will see that it is lowest in stems, followed by blossoms, leaves and roots. The highest Pb values were measured in leaves of tobacco grown on soils having high lead content in regions located near the source of contamination. Very high Cd values in leaves (13.4–15.4 mg/kg) were measured in these regions. The data of Jancheva *et al.* 2007 showed that up to 21.8 mg/kg of cadmium were accumulated in leaves of oriental tobacco grown near an industrial source of contamination. Apparently, tobacco is a crop, accumulating large cadmium quantities in leaves and acting as a hyper accumulator of this element. In regions located away from a source of contamination cadmium concentration in tobacco was lower than the concentrations considered critical to plants: 5 -30 mg/kg (Kabata Pendias and Pendias 1989). If you trace the Cd content in the separate parts of tobacco plants you will see that it was highest in leaves, followed by roots, blossoms and stems.

For the studied tobacco the average copper content in leaves of the lower, medium and upper harvesting zone was within the range from 21 to 30 mg/kg. It was higher than the content, cited in some scientific sources (Adamu 1988; Campbell 2000) – from 5 to 10 mg/kg, but it complied with the results obtained by other authors (Radojicic *et al.* 2003; Pelivanoska 2007).

The zinc content was highest in leaves followed by blossoms, roots and stems. It varied from 8.5 to 138.6 mg/kg in leaves as the highest values were measured in soils having higher total and mobile Zn content. Increase of the average and minimum values from lower to upper harvesting zones was observed.

Table 2. Content of heavy metals in roots and aboveground biomass of Virginia tobacco (*n* = 37)

Heavy Metals	Statistical index	Roots	Stems	Lower leaves	Middle leaves	Upper leaves	Blossoms
Pb	Mean, mg/kg	14.85	5.27	11.86	13.34	11.60	8.30
	Minimum, mg/kg	0.80	1.00	0.75	0.10	0.10	1.00
	Maximum, mg/kg	88.00	9.00	105.00	117.00	85.00	34.00
	CV, %	150.98	46.83	163.37	200.11	127.53	71.52
Cd	Mean, mg/kg	1.74	0.53	3.81	2.77	3.09	1.16
	Minimum, mg/kg	0.30	0.10	0.60	0.40	0.10	0.10
	Maximum, mg/kg	10.50	2.30	13.40	11.90	15.40	5.20
	CV, %	119.54	97.74	91.80	105.21	118.90	95.07
Cu	Mean, mg/kg	26.05	15.33	21.37	26.71	30.49	28.76
	Minimum, mg/kg	12.60	9.40	3.60	9.20	7.20	17.50
	Maximum, mg/kg	52.20	29.20	52.40	53.80	58.90	45.50
	CV, %	33.90	33.59	54.14	46.20	54.51	27.29
Zn	Mean, mg/kg	44.85	16.42	43.37	51.96	62.86	55.61
	Minimum, mg/kg	25.60	8.50	9.24	17.67	19.20	40
	Maximum, mg/kg	72.40	25.20	112.00	138.60	124.00	80.40
	CV, %	29.65	23.08	68.82	64.40	54.22	14.58

Table 3. Correlation among soil parameters and concentration of Heavy Metals in the Virginia tobacco (n = 37)

Heavy Metals	Soil parameters	Roots	Stems	Lower leaves	Middle leaves	Upper leaves	Blossoms
Pb	pH	ns	ns	ns	ns	ns	ns
	Humus	ns	ns	0.707**	0.628**	0.678**	ns
	Total content	0.407*	ns	0.898**	0.870**	0.844**	0.792**
	Mobile forms	0.602**	ns	0.902**	0.972**	0.864**	0.865**
Cd	pH	ns	-0.411*	-0.370*	-0.351*	-0.555**	-0.496**
	Humus	ns	ns	0.512**	0.725**	0.668**	0.655**
	Total content	ns	ns	0.359*	0.431**	0,350*	ns
	Mobile forms	0.337*	ns	0.460**	0.462**	0,361*	ns
Cu	pH	ns	ns	ns	ns	ns	ns
	Humus	ns	0.332*	ns	ns	ns	0.431**
	Total content	ns	ns	0.628**	0.639**	0.414*	ns
	Mobile forms	ns	ns	0.507**	0.611**	0.681**	0.691**
Zn	pH	ns	ns	ns	ns	ns	ns
	Humus	ns	ns	ns	ns	ns	ns
	Total content	ns	ns	0.620**	0.719**	0.719**	ns
	Mobile forms	ns	ns	0.739**	0.650**	0.650**	ns

ns - no significant correlation;

*correlation is significant at the 0.05 level;

**correlation is significant at the 0.01 level

The results of the conducted correlation and regression analysis showed that statistically significant dependencies were determined between pH of soils and cadmium content in all organs of tobacco plants (Table 3). The obtained results complied with the data, indicated in other scientific sources, which referred mainly to the relation between pH and element content in leaves (Gondola and Kadar 1995; Golia *et al.* 2003). pH increase led to reduction of Pb, Cu and Zn concentration in plant organs but these relations were not statistically proven.

The humus content influenced mainly Pb and Cd accumulation in leaves of the three harvesting zones and of Cu in stems and blossoms. The third order polynomial model (cubic model) adequately reflected the relation between humus and content of lead and cadmium at a critical level of significance of 0.01. There were no statistically significant dependencies determined between humus and zinc concentration in tobacco plants.
The Pb content in leaves and blossoms increased linearly with the increase of the total element content in soils. The observed level of significance (α_s) had a value smaller than the critical level of significance of

0.01; the correlation coefficients were high and statistically significant. The determination coefficients showed that approximately 70-80% of the values of lead concentration in leaves and 60% of the values of lead concentration in blossoms depended on the total element content in soils. The increase of the total cadmium, copper and zinc content in soils led to increase of their concentration in the leaves of the lower, medium and upper harvesting zone.The increase of mobile lead and copper in soils resulted in the increase of the element content in leaves of the three zones and in blossoms. Statistically significant relations were determined between mobile cadmium and element content in roots and leaves of the three zones. The third order polynomial model adequately reflected the dependence of zinc content in leaves on mobile zinc content in soils.

Conclusions

1. Statistically significant dependencies were established between soil reaction and Cd content in leaves, stems and blossoms of Virginia tobacco. pH increase led to reduction of Pb, Cu and Zn concentration in plant organs but these relations were not statistically proven.
2. The humus content influenced Pb and Cd accumulation in leaves of the three harvesting zones and of Cu in stems and blossoms. There were no statistically significant dependencies determined between humus and Zn concentration in tobacco plants.
3. Statistically significant dependencies with varying degree of correlation were established between total Pb, Cd, Cu, Zn content, their mobile forms in soil and element concentration in plant organs (mainly in leaves) of Virginia tobacco.
4. The obtained regression dependencies in the soil-tobacco system may be used for solving various scientific as well as scientific and practical tasks for prognostication and prevention of tobacco heavy meal contamination.

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