SOIL QUALITY FOR SUSTAINABLE PRODUCTION OF SUNFLOWER AND SOYBEAN

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ABSTRACT: The production plots of three large sunflower and soybean growers in the Vojvodina Province (AIC »Bečej« in Bečej, »Agrodunav« in Karavukovo and »Graničar« in Adaševci) were analyzed in 2002 and 2003, as a part of the project titled "Soil characterization and land management for production of high-value food from sunflower and soybean". Soil samples taken from profiles (24) and topsoil (55) were analyzed for more than 30 parameters, i.e., physical properties, main chemical properties, total contents of microelements and heavy metals, contents of polycyclic aromatic hydrocarbons (PAHs) and the activity concentration of radionuclides.

Key words: soil properties, soil fertility, harmful and hazardous substances, sunflower, soybean

INTRODUCTION

Soil is a dynamic resource, made up of different sized mineral particles, organic matter, and numerous species of living organisms. Thus, soil has biological, chemical, and physical properties, some of which are dynamic and can change in response to how soil is managed. Soil quality can be defined as the capacity of a soil to sustain plant and productivity with minimal impact on the wider environment (Beare et al., 1997). In general, high quality agricultural soils have high nutrient availability and aeration, good infiltration and retention of water, are structuraly stable, and promote a high level of biological activity. It is generally accepted that intensive agricultural production leads to a decline in soil quality. For this reason, it is essential that soil quality is monitored to avoid degradation, and in so doing, preserve the production capabilities of the land and protect the wider environment.

To assess the soil quality in the Vojvodina Province, 1,600 soil samples from representative locations distributed over the entire territory of the Province were gathered and analyzed in 1993 (Kastori, 1993). This, as well as a subsequent study of the fertility and contents of harmful and hazardous substances in the soils of the Vojvodina Province (Hadžić, 1996), showed that the Province is a suitable agroecological region for

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production of safe and quality food. This, however, does not preclude a possibility that some locations, due to long-term excessive application of chemicals or due to neglect to return nutrients taken with agricultural yield, are subject to contamination and soil degradation. To prevent such problems, the Ministry of Science, Technology and Development of the Republic of Serbia started a project within the National Program of Biotechnology and Agroindustry. The project was titled “Soil characterization and land management for production of high-value food from sunflower and soybean” (BTN.1.1.1.4162.B). The objectives of the project are to make certificates on soil quality for the surveyed locations and to prepare maps showing soil fertility and contents of harmful and hazardous substances. This paper reviews a part of the results obtained within the project regarding chemical indicators of soil quality.

MATERIAL AND METHOD

On-site survey

With intention of striving to achieve the level of food quality required by the National Program of Biotechnology and Agroindustry, arable land surveys were conducted in 2002 and 2003, with three large producers of sunflower and soybean in the Vojvodina Province, AIC "Bečej" in Bečej, "Agrodunav" in Karavukovo, and “Graničar” in Adaševci. Soil samples taken from 24 profiles and 55 "average samples" of topsoil represented 300 ha of arable land which are used for sunflower and soybean growing. Each average sample consisted of 20-25 individual samples, each meant to represent 5 ha of arable land.

Laboratory analyses

The chemical soil properties and the contents of harmful and hazardous substances were analyzed in the Agroecology Laboratory of the Department of Soil, Agroecology and Fertilizers, Institute of Field and Vegetable Crops in Novi Sad. Activity concentrations of natural and artificial radionuclides were determined in the referent laboratory of the Department of Nuclear Physics, Institute of Physics, Faculty of Natural Sciences in Novi Sad.

The water-physical and chemical soil properties were analyzed with the conventional methods. Total contents of microelements and heavy metals, Cu, Zn, Pb, Cd, Ni and Cr, were determined on an AAS Varian Spectra 600 after digesting the samples by boiling them in HNO_3 and adding H_2O_2 (Alloway, 1995).

PAHs were extracted from soil samples with carbon dioxide, using a supercritical fluid extractor system HP 7680A. Soil extracts were analyzed on a liquid chromatograph HP 1100. Chromatographic separation was done using the mobile phase acetonitrile/water (35/75) and the column C-18, 2.1 mm inner diameter, 200 mm in length. Identity of compounds was confirmed by a dioade array detector (DAD). Activity concentrations of members of natural series, ^{238}U, ^{232}Th, ^{40}K, and artificial isotopes, primarily ^{137}Cs, were measured with a high-resolution γ-spectrometer system manufactured by Ortec.

RESULTS AND DISCUSSION

Table 1 shows the results of basic chemical soil properties. The soil in the location Karavukovo had an alkaline reaction, it was calcareous and medium provided with humus. The contents of available phosphorus and potassium were low and they should be increased by fertilization.

In the location Bečej, the soil was calcareous, alkaline, medium provided with humus and total nitrogen. The high contents of available phosphorus and potassium indicate that moderate phosphorus and potassium fertilization is required. The soil in the location Adaševci had an alkaline reaction, it was calcareous and medium provided with humus. The content of available phosphorus was low and it should be increased by fertilization; the optimum content of potassium should be maintained by returning the amounts of potassium removed by agricultural yield.

Tab. 1 - Basic chemical soil properties

Location and no. of samples	Variation range, mean value	pH		$CaCO_3$ %	Humus %	N %	P_2O_5	K_2O
		KCl	H_2O				mg/100g	
Karavukovo 13	Min	7.22	8	2.51	2.57	0.138	6.96	8.2
	Max	7.39	8.23	15.08	3.59	0.243	12.1	10.9
	Average	**7.31**	**8.12**	**7.97**	**3.05**	**0.12**	**9.93**	**9.5**
Bečej 30	Min	6.78	7.91	0.68	2.41	0.142	16.8	20
	Max	7.75	8.47	23.37	4.29	0.272	54.7	54.5
	Average	**7.47**	**8.14**	**13.08**	**3.71**	**0.24**	**29.1**	**31.82**
Adaševci 12	Min	7.06	8.06	4.25	2.77	0.206	4,8	16.4
	Max	7.34	8.30	13.17	4.05	0.265	10.7	32.7
	Average	**7.14**	**8.15**	**9.48**	**3.36**	**0.24**	**8.23**	**20.3**

The contents of the analyzed heavy metals (Table 2) were much below the maximum allowed concentrations (MACs). Taking in consideration the alkaline reactions of the soils in both locations, it is not reasonable to expect high mobility and availability of these elements to plants.

The presence of the 14 characteristic PAHs is given in Table 3. Naphtalene, fluorene, anthracene, and fluoranthene were detected in all three locations. The other PAHs were below the detection level of the analytical system used. The average values of the total PAH contents in the locations Bečej, Karavukovo and Adaševci were 0.282, 0.495 and 1.152 mg kg^{-1} of absolutely dry soil, respectively. These average values are in agreement with literature data for total PAH contents in urban soils (Ayaka and Queency, 1999). Comparing the obtained values for PAHs and the minimum risk level established by USEPA (1993) which, for benzo(a)pyrene amounts 0.1 mg/kg, it was found that the total average PAH content in the analyzed soils above the limit of minimum risk. It can be seen that the criteria used in the USA are much stricter than those used in Europe. In Poland, for example, PAH residues may be 0.2 to 10 mg kg^{-1} in

agricultural soil, while the level for industrial soil is as high as 50 mg kg^{-1}. In our country, maximum allowed concentration (MAC) for the total PAH contents has been determined only for soils used in organic agriculture (1 mg kg^{-1}).

Tab. 2 - Total contents of microelements and heavy metals (mg kg^{-1})

Location and no. of samples	Variation range, mean value	Cu	Zn	Fe*	Mn	Co	Pb	Cd	Ni	Cr
Karavu-kovo 13	Min.	19.90	46.43	18.98	221.0	10.21	19.12	0.33	30.50	21.97
	Max	29.20	74.60	24.60	433.7	15.48	29.62	1.23	43.07	35.83
	Average	**25.20**	**62.58**	**22.43**	**320.3**	**13.70**	**25.09**	**0.77**	**36.53**	**27.92**
Bečej 30	Min	16.97	44.83	18.50	437.0	10.80	20.25	0.37	34.17	6.53
	Max	31.83	88.90	60.77	632.7	26.17	54.00	2.93	47.20	29.27
	Average	**20.13**	**52.57**	**27.75**	**554.6**	**15.88**	**32.33**	**1.53**	**36.37**	**19.23**
Adaševci 20	Min.	20.00	46.60	45.92	378.7	11.50	26,17	1.00	37.30	13,50
	Max	23.07	51.83	50.90	535.3	17.40	39.47	1.43	42.10	16.47
	Average	**21.13**	**49.53**	**48.11**	**442.0**	**14.48**	**32.55**	**1.24**	**39.01**	**14.98**
MAC**		100	300		1000		100	3	50	100

* Fe = g kg^{-1}

** MAC = Rules on allowed concentrations of harmful and hazardous substances in soil and irrigation water and methods of testing, Official Gazette of the Republic of Serbia 23/1994.

The contents of the analyzed PAHs (Table 3) were below the maximum allowed concentrations (MACs) in the locations Karavukovo and Bečej. However, in two composite soil samples taken from Adaševci, the total PAH contents were above MAC value (1.152 mg kg^{-1}). However, taking in consideration that these PAHs are in the soil and that their uptake by plants depends on their concentration and size of molecules, as well as that there is no firm correlation between the PAH level in soil and in plants grown on it because plants also tend to take up these compounds from air, it may be concluded that the PAH levels observed in the soil samples from Bečej, Karavukovo and Adaševci won't jeopardize the production of safe food.

The results of the measurements of activity concentration of radionuclides in the soil are presented in Table 4. Radionuclide ^{137}Cs was present in all soil samples. It originates from the Chernobyl disaster in 1986. Since the halflife of this radionuclide is 30 years, it will be present for a long time in the ecosystem of the Vojvodina Province. The high standard deviation and the large difference between the minimum and maximum concentrations exhibited by ^{137}Cs are typical of an artificial contaminant. The ratio between ^{238}U and ^{226}Ra did not vary much in the analyzed samples. Since the concentration of ^{238}U was at the normal level in all samples, it may be concluded that there were no indications of the presence of depleted uranium. The activity of the natural radioactive series ^{232}Th and ^{40}K were within normal limits. A general conclusion may be drawn that the analyzed soil samples did not indicate increased radioactivity that would jeopardize food production in the examined locations. The measured activity of ^{137}Cs, taking into consideration

the isotope's transfer factors into plants, should not threaten the safety of the produced food. As shown in Table 4, the activity of all radionuclides except ^{137}Cs was below the detection limit.

Tab. 3. Contents of PAHs in the soil (mg kg^{-1})

Location		Naphtalene	Acenaphthylene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	dibenzo(a,h)anthracene	Pyrene	Benza(a)antra	Chrysene	Benzo(b)fluor	Benzo(k)fluor	Benzo(a)pyrene	Indeno(1.2.3-	*Total*
KAR	Min	0.045	nd	0.084	nd	nd	0,032	0.062	nd	nd	nd	nd	nd	nd	nd	**0.094**
	Max	0.081	nd	0.127	nd	0.128	0,057	0.288	nd	nd	nd	nd	nd	nd	nd	**0.473**
	x	**0.061**	**nd**	**0.104**	**nd**	**0.079**	**0.042**	**0.160**	**nd**	**nd**	**nd**	**nd**	**nd**	**nd**	**nd**	**0.282**
BEC	Min	0.005	0.013	nd	0.021	0.001	0.008	0.032	0.055	0.003	0.001	0.001	nd	nd	nd	**0.140**
	Max	0.058	0.487	0.101	0.090	0.148	0.101	0.079	0.126	0.061	0.073	0.002	nd	nd	nd	**1.326**
	x	**0.027**	**0.108**	**0.033**	**0.040**	**0.094**	**0.030**	**0.050**	**0.082**	**0.013**	**0.015**	**0.002**	**nd**	**nd**	**nd**	**0.495**
ADA	Min	0.006	0.672	nd	0.031	0.082	0.011	nd	0.046	nd	0.001	nd	nd	nd	nd	**0.977**
	Max	0.009	0.922	0.008	0.041	0.095	0.012	nd	0.055	0.005	0.004	0.004	0.007	0.019	0.115	**1.296**
	x	**0.008**	**0.797**	**0.008**	**0.036**	**0.089**	**0.012**	**nd**	**0.051**	**0.005**	**0.003**	**0.004**	**0.007**	**0.019**	**0.115**	**1.152**

Location: KAR – Karavukovo, BEC – Bečej, ADA – Adaševci
x Mean value

Tab. 4. Mean values, standard deviation, minimum and maximum concentrations of radionuclides in the soil [Bq/kg]

Radionuklide [Bq/kg]	$\bar{A}_s$	$\sigma \bar{A}_s$	A_s (min)	A_s(max)
^{137}Cs	7	3	4.2	11.1
^{238}U	48	12	34	70
^{226}Ra	42	3	38	46.5
^{232}Th	45	5	38.5	47.3
^{40}K	559	28	511	586

Based on the results of the analyses of soils from the locations Karavukovo, Bečej, and Adaševci, it was concluded that regarding the chemical properties, the low alkaline soil reaction, should be meliorated by applying physiologically acid fertilizers. The low contents of available phosphorus (locations Karavukovo and Adaševci) and potassium (location Karavukovo) should be increased by fertilization.

Based on the obtained values for PAHs, it was concluded that the total average PAH contents in the analyzed soils were much above the limit of minimum risk, but still much below the maximum allowed concentrations permitted in Poland. It was therefore con-

cluded that the observed PAH level won't jeopardize the production of safe food. It remains to establish MACs for the content of PAHs in soil in our country.

The analyzed soil samples showed no indication of increased radioactivity that would jeopardize food production. The measured concentrations of ^{137}Cs, taking into consideration the transfer factors of that isotope into plants, should not endanger the safety of the produced food.

Generally, the quality of soil in the locations of Bečej and Adaševci fully complies with the requirements for the production of high value food from sunflower and soybean. In the location of Karavukovo, adequate agrotechnical measures are needed to improve soil fertility.

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