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HEAVY METALS CONCENTRATION IN SOYBEAN AS AFFECTED BY DIFFERENT TILLAGE SYSTEMS IN BARANJA REGION

Irena Jug[1], Danijel Jug[1], Dušan Kovačević[2], Boris Đurđević[1], Bojan Stipešević[1]

Abstract

Different tillage systems affect the root adsorption of trace elements. Also, under different climatic conditions accessibility of nutrients in the soil decreased during the growing period as low water content in the soil becomes a limiting factor in the transfer of nutrients in the rhizosphere area. The aim of this study was determine effect of conventional tillage, reduced tillage and no tillage on the heavy metal concentration in soybean during three climatic different years. The study was performed in a field experiment at the North-eastern Croatia, in Barany region, on chernozem soil type during the period 2003-2005 with following continuous soil tillage treatments: CT – conventional soil tillage, based on moldboard ploughing; DH – multiple pass diskharrowing; and NT – no-tillage. Soybean was analysed for molybdenum (Mo), cooper (Cu), lead (Pb), nickel (Ni), cadmium (Cd), chromium (Cr), zinc (Zn) iron (Fe), manganese (Mn) and cobalt (Co). There was a significant influence of climatic conditions on the concentration of Zn, Cd, Cr, Mn, Pb and Fe, whereas Tillage influence was mostly indirect, but visible through the interaction Year x Tillage. The effects of tillage were significant only for cooper concentration.

Keywords: heavy metal, soybean, tillage

Introduction

Heavy metals are released into the environment byanthropogenic and natural sources. With the exception of soils derived from the physical and chemical weathering of parent materials containing elevated levels of trace elements, the presence of elevated metal concentrations in the environment is related to man's activities (Jung, 2001;Lee et al., 2001;Lee et al., 2005; Parket al., 2006;Jung, 2008).Heavy metals ions play an important role in complex biochemical reactions: nitrogen fixation, photolysis of water, cell respiration, catalysis of redox reactions and plant growth (Prasad and Hagemeyer, 1999). At high concentrations heavy metals ions produce non-specific complex components in cells that produce toxic effects (Prasad, 1997).The bioavailability of these elements depends upon their chemical forms in soils, which is related to clay content and mineralogy, the organic matter type and content, pH and Eh changes, among other factors.

The distribution patternof micronutrients and other trace elements in topsoils is usually modified by the tillage systems (Scheiner and Lavado, 1998; Lavado et al., 2001). Moreover, tillage techniques affect some soil properties like concentration of organic matter or pH value. This gives rise to changes in bioavailability of several elements in root biomass distribution. All these processes affect the root absorption of trace elements (Carter and

[1] Doc. dr. sc. Irena Jug (ijug@pfos.hr), prof. dr. sc. Danijel Jug, dr. sc. Boris Đurđević, prof. dr. sc. Bojan Stipešević – University of J. J. Strossmayer Osijek, Faculty of agriculture, Trg Sv. Trojstva 3, 31000 Osijek
[2] Prof. dr. sc. Dušan Kovačević –University of Belgrade, Faculty of agriculture, Nemanjina 6, 11080 Belgrade-Zemun

Gupta, 1997). Tillage does not affect element absorption in a single way. In addition, nutrient availability changes continuously due to application of macro-, micronutrients and other trace elements through fertilizers, biosolids, irrigation water or through indirect sources (i.e. rainfall and atmospheric deposition from several sources). These changes in soil also affect the influence of tillage systems on the absorption of nutrients and other elements. Tillage for soybean is mostly based on conventional technology, although in some studies reduced soil showed a positive trend in the nitrogen fixation ability (Jug et al., 2005). Different tillage systems affect the root adsorption of trace elements (Jug et al., 2010).

Also, under different climatic conditions accessibility of nutrients in the soil decreased during the growing period as low water content in the soil becomes a limiting factor in the transfer of nutrients in the rhizosphere area (Marschner, 1995).

The aim of this study was determine effect of conventional tillage, reduced tillage and no tillage on the heavy metal concentration in soybean during three climatic different years.

Material and method

The field experiment

Field experiments were conducted at Kneževo site in NorthernBaranya region for soybean (Glycine max L.), cultivar Tisa in the period 2003-2005.Before sowing, soybean seed was inoculated with nitrate-fixing symbiotic bacteria Bradyrhizobiumjaponicum (trade-mark "Biofiksin-S") from the collections of the Department of Microbiology, Faculty of Agriculture in Zagreb. The main experimental set-up was a complete randomized block design in three replications, with three continuing soil tillage systems: CT – conventional tillage with ploughing up to the 30 cm as a primary tillage, followed by diskharrowing, sowing preparation and sowing with no-till driller John Deere 750A; DH – diskharrowing only up to the 15 cm and sowing as for CT and NT – No-tillage sowing without any primary tillage operation. The experimental site soil is classified as a calcareous chernozem on loess substrate (FAO, 1990). The soil analyses presented very favourable chemical properties (pH in H_2O = 8.1, pH in 1mol dm^{-3}KCl = 7.7; humus = 3.1%, $CaCO_3$ = 2.6%; AL-soluble P_2O_5 and K_2O = 13.5-14.7 and 25.2-27.3 mg $100g^{-1}$, respectively). The size of basic experimental plot was 900 m^2. The fertilization was uniform across treatments and years, and it consisted of N:P_2O_5:K_2O = 40:130:130 kg ha^{-1}. Harvest of soybean was made by a small plot harvest combine.

Weather conditions

Climatic conditions studied years (Table 1), differed significantly according to rainfall during the growing period from emergence to early pod formation (April-July). Amount of precipitation in 2003 was 158 mm less than in 2004 and 378 mm lower compared to 2005. Amount of precipitation in 2005 was 220 mm higher than in 2004. So, in the mutual comparison of all three years of investigation can be concluded that in 2003 was extremely dry, 2005 was extremely wet year, and 2004 was year with average amount precipitation (according to long term means).

Table 1: Precipitation and mean air-temperatures

Knezevo (N:45°82′, E:18°64′): 2003-2005 and long-term means (LTM: 1965-2004)								
Month	Precipitation (mm)				Mean air-temperatures (^oC)			
	2003	2004	2005	LTM	2003	2004	2005	LTM
May	33	77	55	58	20.0	14.9	17.0	16.5
June	19	114	88	88	24.5	19.5	20.4	19.7
July	61	41	168	68	22.8	21.9	21.4	21.2
August	23	52	155	54	24.7	21.6	19.7	20.9
Sept.	34	43	82	55	16.4	15.9	17.5	16.4
Total	170	328	548	323	21.7	18.8	19.2	18.9

Plant sampling and analysis

Sampling of soybean was made in the R-4 (full-developed pods) soybean stage. The samples (three replications of each treatment: total 27 samples) were prepared for chemical analyses by microwave digestion using 65% HNO_3 + 30% H_2O_2. Analyses of10 elements (Zn, Mn, Fe, Cu, Mo, Co, Ni, Cr, Pb, Cd) were performed with a Jobin-YvonUltrace 238 ICP-OES spectrometer in the laboratory of the RISSAC, Budapest, Hungary.

Statistical analysis

The statistical analysis for all data were processed by two-way ANOVA with significant differences P<0.05.

Results and discussion

In general, concentrations of heavy metals were under significant influence of climatic conditions in growing season (Table 2). The average concentration of zinc was 26.93 mg kg^{-1}. Lowest concentration of zinc was detected in dry year (2003), although statistically not different from2005. Significantly higher concentration of zinc was measured in soybean in 2004 (34.34 mg kg^{-1}). Lower Zn concentration in 2005 was probably due to the higher precipitationwhichis in accordance with the finding of Jug (2008). Plants without zinc are expressing common signs of Zn deficiency such as stuntedgrowth, small leaves, chlorosis and shortening of internodesand other signs of low protein synthesis.The soybean did not express any Zn uptake imbalance regardless the soil tillage applied which is in accordance with the finding of Stipešević et al. (2009).

Manganese (Mn) is recognized as an essential microelement for the growth of plants including soybean. Mn availability to plants is dependent on a number of factors, the major ones including soil pH, soil moisture, oxide-reduction conditions and microbial activity (Hebbern et al., 2005). According results, concentration of Mn was under significant influence of climatic conditions. The highest value of Mn was detected in “dry” year, 2003 (111 mg kg^{-1}) while the concentration of Mn in soybean from 2004 (69 mg kg^{-1}) and 2005 (84 mg kg^{-1}) was not statistically different. Mn can be critical in maximizing N_2 fixation activity of soybean, particularly under soil water deficit conditions (Vadez et al., 2000).

Table 2:Influences of the growing season(A) and soil tillage (B) on heavy metals concentrations in soybean above-ground biomass

Year	Tillage	(mg kg^{-1} on dry matter basis)									
A	B	Zn	mean	Mn	mean	Fe	mean	Cu	mean	Mo	mean
2003	CT	21.10		90		296		10.32		0.345	
	DH	21.60		105		261		6.74		0.122	
	NT	24.60		137		596		8.93		0.126	
	mean	22.43		111		384		8.66		0.198	
2004	CT	33.10		72		239		10.97		0.127	
	DH	33.27		65		217		10.59		0.178	
	NT	36.67		69		231		9.31		0.072	
	mean	34.34		69		229		10.29		0.126	
2005	CT	26.63		86		398		10.90		0.420	
	DH	26.73		95		259		9.22		0.254	
	NT	18.70		71		187		8.50		0.266	
	mean	24.02		84		281		9.54		0.313	
	mean	26.93		88		298		9.50		0.212	
LSD A $_{0.05}$		5.09		33		175		n.s.		n.s.	
LSD B $_{0.05}$		n.s.		n.s.		n.s.		1.61		n.s.	
Year	Tillage	(mg kg^{-1} on dry matter basis)									
		Co	mean	Ni	mean	Cr	mean	Pb	mean	Cd	mean
2003	CT	0.110		2.247		0.521		0.332		0.034	
	DH	0.112		1.707		0.457		0.306		0.041	
	NT	0.258		1.547		0.848		0.371		0.050	
	mean	0.160		1.833		0.609		0.336		0.042	
2004	CT	0.186		1.780		0.436		0.300		0.020	
	DH	0.160		2.200		0.388		0.300		0.027	
	NT	0.142		1.527		0.396		0.322		0.039	
	mean	0.163		1.836		0.406		0.307		0.028	
2005	CT	0.239		2.717		0.607		0.529		0.130	
	DH	0.160		2.270		0.390		0.493		0.062	
	NT	0.124		2.337		0.353		0.489		0.066	
	mean	0.174		2.441		0.450		0.503		0.086	
	mean	0.166		2.037		0.488		0.382		0.052	
LSD A $_{0.05}$		n.s.		n.s.		0.232		0.076		0.038	
LSD B $_{0.05}$		n.s.		n.s.		n.s.		n.s.		n.s.	

Iron is most important for the respiration and photosynthesis processes and also implied in many enzymatic systems like chlorophyll synthesis. Iron deficiency and chlorosis is aggravated by cool soil temperatures and conditions that restrict air movement into soil: plastic sheet mulching, compaction, and water-saturated conditions. Chlorosis is often more

severe where topsoil has been removed exposing lime enriched subsoil (Jug, 2008). Iron concentration (the average was 298 mg kg^{-1}) was significantly influenced by climatic conditions. The highest value was detected in soybean in 2003 and the lowest concentration was measured in soybean in 2004. Differences between Fe concentration in soybean growth 2004 and 2005 was not statistical significant.
Higher amount of precipitation lead to reduction conditions in soil. As a consequence of reduction conditions is decrease of pH soil witch lead to increases accessibility of Fe.Concentration of Fe, Co and Cr was under significant influence of interaction Year x Tillage (Table 3).

Table 3: Impact of interaction (Year x Tillage) on heavy metals concentrations in soybean above-ground biomass

A	B	Fe (mg kg^{-1})	Cr (mg kg^{-1})	Co (mg kg^{-1})
2003	CT	296	0.521	0.110
	DH	261	0.457	0.112
	NT	596	0.848	0.258
	mean	384	0.609	0.160
2004	CT	239	0.436	0.186
	DH	217	0.388	0.160
	NT	231	0.396	0.142
	mean	229	0.406	0.163
2005	CT	398	0.607	0.239
	DH	259	0.390	0.160
	NT	187	0.353	0.124
	mean	281	0.450	0.174
LSD AB $_{0.05}$		236	0.302	0.108

Concentrations of Cr, Pb and Cd were under significant influence of climatic conditions in investigated years whereas tillage influenced was absent. The highest value of Pb and Cd was detected in 2005 (0.503 mg Pb kg^{-1} and 0.086 mg Cd kg^{-1}). These concentrations were greater than concentrations of Pb and Cd in soybean mass in 2004 and 2003 (Table 2) whereas differences between these years wasn’t statistical significant.
Concentration of cooper was under significant influence of tillage treatment. These results showed that Cu concentration was significantly higher under CT treatment. The lowest value of Cu concentration was measured in soybean above-ground biomass on NT treatment (Lavado et al., 2001).
Concentration of Ni, Co, Mo was not affected by climatic conditions or tillage treatments.

Conclusion

According achieved results were found a significant influence of climatic conditions on concentration of heavy metals (concentration of Zn, Pb and Cdwas higher in years with higher rainfall, while the concentration of Mn, Fe and Cr was significantly affected by drought), whereas Tillage influence was mostly indirect, but visible through the interaction Year x Tillage.
Based on our study, reduction or absence of soil tillage under conditions of calcareous chernozem of Baranya province had not serious consequences on heavy metal status in soybean. The effect of tillage was significant only for the concentration of cooper.

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