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Vermicompost effect on the trace elements distribution in the luvic chernozem of the Krasnoyarsk forest-steppe

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Abstract. In the field experiment (2016-2018) in the conditions of the Krasnoyarsk forest-steppe the number of trace elements mobile forms were determined and the effect of soil organic matter and increasing doses of vermicompost on their distribution in luvic chernozem was studied. It is established that the studied vermicompost does not pollute the soil, which allows its widespread use in agriculture. The correlation and regression analysis obtained linear regression equations that reflect the relationship of the chemical element and organic matter in the soil after using increasing doses of vermicompost adequately. Elements with positive correlation and high significance level include Mn, Cu, Co and Zn.

1. Introduction

It is necessary to know the trace elements distribution in soils and plants for the development of science-based systems of fertilizer application in modern agricultural technologies. Both insufficient provision of arable soils with microelements mobile forms and their increased content can lead to the reduction in the ecosystems productivity, in addition, their high amount in the soil can be toxic to plants and worsen the quality of crops significantly [1]. In this regard, the levels of low soil content, at which it is necessary to use micronutrients and the maximum permissible levels (MPC), in excess of which there is need to carry out measures for soil detoxification [2] are established for the main trace elements.

Microelements are the elements contained in organisms and soils in very small quantities (10^{-3} % or less) without which the vital activity of plants is difficult or impossible.

The biochemical role of metals depends on their concentration. With a shortage of content they are considered as trace elements, in excess - as heavy metals (HM). Trace elements in toxic concentrations are called heavy metals. They include chemical elements with the atomic mass greater than 50 [3]. According to the danger degree chemical elements are divided into three classes: 1- highly dangerous (Cd, Pb, Zn, As, Hg), 2 - moderately hazardous (Ni, Cu, Cr, Co, B, Mo), 3 - low-risk (V, Sr, Mn) [4]. The study of trace elements content in soil is important for soil monitoring.

The trace elements mobility in the soil, the forms of their presence in the soil, phytotoxicity and accumulation in plants, migration to adjacent environments are determined by the sorption capacity of soils, which to some extent limits their mobility and biological availability.

In turn, the sorption capacity of soils in respect of trace elements depends on soil acidity, redox conditions, mineralogical and granulometric soils composition, organic matter content, etc. [5-7].

Therefore, the aim of this work was to study the action of vermicompost organic matter on the trace elements distribution in the soil.

2. Methods and results

The research was conducted in the field in the agricultural part of the Krasnoyarsk forest-steppe (56^0 n.l. and 92^0 e. l.) in 2016-2018. The object of study was medium-sized, heavily loamy luvic chernozem on the yellow-brown clay. The arable horizon of this soil was characterized by high humus content, neutral reaction of soil solution, high availability of mobile phosphorus (280.8 mg/kg) and very high of exchangeable potassium (230.4 mg/kg).

The latter is typical for the soils of the Krasnoyarsk territory and is a consequence of the potassium enrichment in the parent rocks of heavy particle size distribution.

The vermicompost used in the experiments is an organic fertilizer obtained by the method of poultry manure and sawdust processing by Californian worm Eiseniafetida in the soil science and agricultural chemistry department of the Krasnoyarsk state agrarian university. It contained in its composition 20.3% of organic matter (state standard 27980-88); 1.3% of the total nitrogen (state standard 26715-85) and 0.98 of potassium (state standard 26718-85); 3 % of total phosphorus (state standard 26717-85); 0.29% of ammonia nitrogen (state standard 26716-85); it had pH= 6,8 (state standard 27979-88).

Changes in the content of trace elements mobile forms in the soil under the influence of increasing doses of vermicompost were studied in the field according to the following scheme: 1) Control without fertilizers. 2) Vermicompost (VC), 3 t/ha. 3) VC, 5 t/ha. 4) VC, 7 t/ha. The total area of the plot was 10 m^2, repeat seeding was fourfold, serial arrangement. Vermicompost was introduced into the soil annually in spring and closed up to depth of 14-20 cm.

The potato variety «Aramis» was cultivated. Soil samples were collected with agro-chemical drill from the 0-20 cm soil layer in the dynamics in spring before planting potatoes and in autumn after the harvest. pH_{H2O}, organic matter content and mobile forms of trace elements were determined in these samples at the research test center of the KSAU.

The results were processed statistically by the method of dispersion and correlation-regression analysis using the program Microsoft office Excel.

One of the content sources of chemical elements mobile forms in the soil is vermicompost used in these experiments organic fertilizer. As a result it was found that the content of all the studied chemical elements in the soil does not exceed the maximum permissible concentrations (MPC). Luvic Chernozem is characterized by low Cu availability according to the grades [4]. The vermicompost introduction into the soil did not have a noticeable effect on the Cu content in the soil, only the tendency of its increase for the entire period of research was noted (table 1). Soil is poor in Zn. Vermicompost soil application contributed to the increase in the number of that element on 30-59 % of control in 2016 and 74-133% in 2017. At the same time it should be noted that the Zn amount increased from a very low level in the control to a low security class in the options fertilized with vermicompost.

The soil is characterized by high Co availability. Under the action of 3 and 7 t/ha of vermicompost a decrease in Co content by 7 - 14% in spring 2016 was noted. However, its number increased in autumn after harvesting potatoes. The dynamics showed an increase in this indicator, but within the same security class. Luvic chernozem is characterized by high Mn content throughout the observation period. However, its amount decreases to autumn in all variants of the experiment (table. 1). The soil is characterized by high Pb amount, but its values do not exceed the MPC.

Under the vermicompost influence there was a change in its number depending on the year of research, but the content remained within the same high security class according to gradations [4]. The results showed that the Cd amount in the soil was high, but not exceeding MPC.

Under the influence of different vermicompost doses in chernozem there was a change in the content of this element, but by a statistically insignificant amount. Ni soil security is average, having the growth tendency in dynamics and under the action of introduced vermicompost. However, it remains within the same security class.

Table 1. Vermicompost influence on the content dynamics of chemical elements mobile forms in luvic chernozem, mg/kg.

Chemical element		Control (without fertilizers)	VC 3 t/ha,	VC 5 t/ha,	VC 7 t/ha,	SSD_{05}	MPC [4]
				2016			
Cu	M	0,32±0,05	0,23±0,04	0,29±0,03	0,23±0,03	0,11	5
	±	0,25±0,01	0,25±0,03	0,27±0,03	0,24±0,02	0,08	
Zn	m	0,73±0,09	0,76±0,09	0,79±0,10	0,68±0,09	0,29	20
		0,70±0,08	0,91±0,18	1,06±0,10	1,11±0,18	0,44	
Co		0,69±0,03	0,59±0,01	0,72±0,02	0,64±0,02	0,07	3
		0,69±0,06	0,70±0,03	0,81±0,04	0,67±0,03	0,13	
Mn		63,85±1,13	64,69±2,44	65,27±1,20	61,89±2,78	6,24	100
		60,79±1,41	62,02±2,12	62,45±1,82	56,98±4,36	8,27	
Pb		2,52±0,18	2,42±0,11	2,44±0,10	2,65±0,11	0,39	5
		2,81±0,05	2,71±0,23	2,70±0,22	2,36±0,05	0,49	
Cd		0,15±0,01	0,15±0,01	0,17±0,01	0,16±0,01	0,02	1,0
		0,18±0,01	0,17±0,01	0,18±0,01	0,16±0,01	0,03	
Ni		0,75±0,05	0,70±0,07	0,76±0,05	0,75±0,03	0,16	5
		0,79±0,05	0,79±0,05	0,87±0,05	0,70±0,08	0,19	
				2017			
Cu	M	0,31±0,01	0,29±0,02	0,29±0,03	0,29±0,01	0,06	5
	±	0,29±0,02	0,28±0,03	0,30±0,05	0,31±0,03	0,11	
Zn	m	0,60±0,09	0,68±0,06	0,68±0,05	0,59±0,04	0,20	20
		0,57±0,10	1,06±0,14	0,99±0,12	1,33±0,16	0,40	
Co		0,76±0,06	0,82±0,08	0,88±0,08	0,84±0,09	0,24	3
		0,79±0,03	0,78±0,03	0,84±0,10	0,80±0,07	0,20	
Mn		59,16±1,13	60,86±1,80	61,72±2,17	62,77±4,28	5,87	100
		56,56±1,49	56,99±1,65	58,47±3,04	57,04±2,82	7,26	
Pb		3,05±0,24	2,96±0,23	3,15±0,33	3,15±0,29	0,85	5
		3,14±0,15	3,06±0,32	3,44±0,36	3,37±0,29	0,89	
Cd		0,17±0,01	0,18±0,02	0,17±0,03	0,17±0,02	0,06	1,0
		0,15±0,01	0,16±0,02	0,16±0,02	0,17±0,02	0,06	
Ni		0,93±0,06	0,93±0,07	0,99±0,14	1,03±0,14	0,34	5
		1,05±0,07	1,00±0,06	1,04±0,14	0,99±0,14	0,34	
				2018			
Cu	M	0,43±0,03	0,42±0,02	0,42±0,03	0,43±0,03	0,08	5
	±	0,45±0,01	0,43±0,01	0,44±0,03	0,45±0,03	0,06	
Zn	m	0,57±0,01	0,57±0,02	0,56±0,04	0,57±0,02	0,08	20
		0,48±0,03	0,54±0,04	0,55±0,05	0,64±0,03	0,11	
Co		0,95±0,06	0,97±0,06	1,00±0,06	1,01±0,08	0,20	3
		0,86±0,04	0,93±0,06	0,94±0,01	0,91±0,06	0,14	
Mn		69,04±1,01	69,88±0,49	70,64±1,99	70,46±2,49	5,21	100
		55,04±1,14	56,86±1,27	54,08±1,81	52,42±2,17	5,09	
Pb		3,31±0,13	3,38±0,05	3,77±0,31	3,58±0,35	0,76	5
		3,37±0,15	3,24±0,05	3,64±0,23	3,42±0,33	0,67	
Cd		0,16±0,01	0,16±0,01	0,16±0,01	0,18±0,01	0,03	1,0
		0,14±0,01	0,15±0,01	0,16±0,01	0,15±0,02	0,05	
Ni		1,16±0,08	1,13±0,05	1,27±0,10	1,23±0,12	0,28	5
		1,11±0,05	1,10±0,06	1,17±0,09	1,16±0,11	0,25	

Note: M–the average element content, ±m–mean error, above the line - content in spring, under the line - in autumn. SSD_{05} –the smallest significant difference between the options.

Chemical compounds can accumulate in the soil especially in the upper humus horizons, their primary transformation and distribution takes place in them. One of the leading factors in the distribution of chemical elements is soil organic matter, which can be estimated by correlation analysis. The correlation and regression analysis obtained linear regression equations that reflect the relationship of the studied parameters adequately: the content of the chemical element and organic matter in the soil after using different doses of vermicompost (table 2). Determination coefficients (R2) show the proportion (percentage) of changes in the chemical element content depending on the amount of organic matter in the soil in this study.

Table 2. Correlation and regression relationships between the content of chemical elements and the amount of organic matter after using vermicompost in the soil.

Chemical element	Control (without fertilizers)		VC 3 t/ha		VC 5 t/ha		VC 7 t/ha	
	equation	R^2	equation	R^2	equation	R^2	equation	R^2
Cu	y = -0,0546x + 0,4691	0,83	y = 0,195x - 0,5613	0,63	y = 0,0681x - 0,0218	0,23	y = -0,0685x + 0,5145	0,39
Zn	y = 0,3294x - 0,6308	0,87	y = 0,9814x - 3,1613	0,48	y = 0,1502x + 0,4217	0,10	y = 0,4882x - 0,8529	0,39
Co	y = -0,231x + 1,6235	0,89	y = 0,0934x + 0,3243	0,61	y = -0,2039x + 1,6772	0,99	y = 0,1032x + 0,2498	0,74
Mn	y = 5,697x + 37,847	0,85	y = 15,633x - 2,811	0,94	y = -4,4412x + 81,331	0,28	y = 17,705x - 14,303	0,84
Pb	y = -,0316x+ 2,9322	0,02	y = 1,2373x - 2,4178	0,52	y = -0,8899x + 6,4795	0,79	y = 0,2301x + 1,4337	0,97
Cd	y = -0,0067x + 0,2041	0,11	y = 0,026x + 0,0651	0,22	y = -0,0511x + 0,3925	0,80	y = 0,0549x - 0,0662	0,98
Ni	y = -0,178x + 1,5094	0,71	y = 0,1411x + 0,2008	0,11	y = -0,1547x + 1,5284	0,50	y = 0,0934x + 0,3243	0,06

The coefficients that have reached the average level and above it are indicated by R in table 3. For the rest only the correlation sign is indicated.

Table 3. Correlation between the content of chemical elements in the soil and the amount of organic matter.

Option	Cu	Zn	Co	Mn	Pb	Cd	Ni
Control (without fertilizers)	-R	R	-R	R	-	-	-
VC 3 t/ha	R	R	R	R	R	+	+
VC 5 t/ha	+	+	-R	-	-R	-R	-R
VC 7 t/ha	-R	R	R	R	R	R	-

Based on the analysis of the obtained data it should be noted that the correlation between the Pb, Cd, Ni content and the amount of organic matter can be estimated as low, not reached the level of significance. There is also low correlation in the variants: Mn-organic matter after using 5 t/ha vermicompost, Ni-organic matter after using 7 t/ha vermicompost. This means that the content of soil organic matter does not affect the amount of these chemical elements and is not a factor for their accumulation. A positive correlation indicates that as the content of organic matter increases the amount of the chemical element also increases. A negative correlation indicates the opposite that with an increase in the content of organic matter the amount of the chemical element will decrease.

In some cases it is the negative dependence that reaches the level of significance. The most clearly negative relationship is between the content of Co, Pb, Ni, Cd and organic matter when 5 t/ha of vermicompost is introduced into the soil, as well as between the content of Cu and organic matter when 7 t/ha of vermicompost is used. Elements with the positive correlation with a high level of significance include Mn, Cu, Co, Zn. On the basis of which it can be assumed that organic matter is a stabilizing factor for these elements.

Thus, in the field experiments there was no MPC excess of chemical elements after increasing doses of vermicompost were introduced into the soil, so vermicompost is safe and can be used in agricultural

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production technologies. It is established that the organic matter content in the soil and vermicompost plays a significant role in the accumulation and distribution of chemical elements: both reducing and increasing their content in the soil, but within the MPC.

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