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Dynamics of Agrochemical Properties of leached Chernozems in the Republic of Mordovia

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ABSTRACT

There is an acceleration, deceleration, or distortion of elementary soil processes under the influence of anthropogenic impact on the soil cover, which dictates the formulation of a state strategy for the rational use of soil resources. The object of the study was the leached chernozems of the Republic of Mordovia, where reference sites with state status were located on permanent spaces and which reflect the level of anthropogenic loads to the maximum extent. Soil sampling was carried out annually in spring before the start of fieldwork. Samples were taken to the depth of the arable layer. The following investigations were carried out in soil samples: humus by the Tyurin method with a photometric end; pHkcl with the preparation of a salt extract and determination of mobile phosphorus and potassium by the method of CINAO by the method of Kirsanov in the modification of CINAO with a photometric end; potassium by the flame photometric method. The trend of humus change indicates that its content in the plowed layer is decreasing. The greatest decrease was noted at reference plots 5 and 21, where in the 80s and 90s high doses of organic fertilizers were applied. Changes in the reaction of the soil solution for 1994–2012 indicate that this indicator is decreasing in all reference plots. The differences between individual plots are relatively small. The content of absorbed bases in the upper layer was quite high. In the arable layer, except for reference plot 5, an increase in mobile phosphorus was observed. The importance of soil-ecological monitoring is increasing immeasurably, which allows identifying deviations from optimal indicators to see a retrospective of natural complexes.

KEYWORDS: HUMUS, LEACHED CHERNOZEM, PHOSPHORUS, POTASSIUM, REFERENCE PLOTS, THE REACTION OF SOIL SOLUTION.

INTRODUCTION

The importance of soil-ecological monitoring of chernozems increases in conditions of active agro-technological impact, i.e., constant monitoring of changes in soil properties, the concept of which was developed in the second half of the 20th century (Lisetskii, 2009). Scholars carry out monitoring of the soil cover by comparing the studied objects with their analogs, establishing their age or the period during which they were in different conditions (Mukha, 1988; Galeeva, 2012). The possibility of assessing modern trends in the development of soils and geosystems, in general, is widely used in the scientific literature, using detailed studies that were carried out by scholars at different times (in the 19th – 20th centuries) (Khitrov, 2008; Eryashev et al., 2017).

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The anthropogenic influence on the development and fertility of chernozems was studied by various methods, the conclusions of scholars are contradictory. According to some researchers (Ivanov, 2002; Eryashev et al., 2015), the involvement of soil in agricultural use leads to a significant decrease in the amount of humus, especially in the arable horizon. A decrease in the humus content of the soil occurs only in the initial period of its plowing, later the loss of humus is less intensive, and then stabilization of its reserves in the arable layer of the formed agrocenosis occurs. Other researchers (Mukha, 2004; Ivanov et al., 2020) point to the preservation of the nature of humus formation and the quality of humus in arable soils (Ivanov et al., 2020).

Under the influence of anthropogenic impact on the soil cover, an acceleration, deceleration, or distortion of elementary soil processes can happen (Lisetskii, 2009; Kashtanov, 2011). This requires a formulation of a state strategy for the rational use of soil resources (Chekmarev & Lukin, 2013; Sukhanovskii et al., 2013). Under the influence of long-term agricultural use, both improvement and deterioration of soil fertility can occur (Ivanov et al., 2013; Eryashev et al., 2016; and changes in the conditions for the growth and development of living organisms (Kargin and Zaharkina, 2016 Kargin et al., 2019).

The main factors causing degradation changes are reduced to hydrological, erosional, chemical, radiological, and mechanical factors (Kashtanov, 1974; Zaidelman, 2009). They can lead to desertification, the development of water and wind erosion; hydromorphism, soil compaction with heavy equipment, contamination with heavy metals and radionuclides, accumulation of soluble salts in the soil, increased salinity of surface and ground waters, destruction of organic matter with the removal of fine soil fraction (Shuvaev et al., 2009). Degradation of ecosystems, a significant decrease in the content of humus, total nitrogen, elements of ash nutrition of plants in soils, and deterioration of agrophysical properties occurs under conditions of intensive use of soils in agricultural production. In such conditions, the importance of soil-ecological monitoring increases immeasurably to identify undesirable deviations from optimal indicators and preserve the potential soil fertility.

MATERIAL AND METHODS

The object of the study was leached chernozems of the Republic of Mordovia, where reference plots (RPs) that had a state status and reflected the levels of anthropogenic loads to the maximum extent were located on permanent sites. The observations were carried out in 1994–2013. by the "Mordovskiy" State center of agrochemical service. The results of those observations were used in the preparation of this paper (Reports of the State center of agrochemical service Mordovskiy for 1994–2013, 2014). Cultivated crops and fertilizers applied at RPs are presented in Table 1.

Table 1. Cultivated crops and applied fertilizers on RPs

District and nearby settlement, RP No.	Year of the layout	Sown crops, number of years	Applied fertilizers, kg/ha of active ingredient per year			
			Nitrogen	Phosphorus	Potassium	Total
Oktyabrsky, Nikolaevka village, 5	1994	Grain crops (10 years), corn (4), perennial grasses (5), complete fallow (1 year)	38.7	26.6	27.2	92.5
Oktyabrsky, Saransk, 8	1994	Grain crops (17 years), annual herbs (2), potatoes (1 year)	23.1	23.2	16.4	62.7
Lyambirsky, Lyambir village, 12	1994	Grain crops (15 years), complete fallow (3), annual herbs (2 years)	16.3	11.1	11.1	38.6
Chamzinsky, Sabur-Machkasy village, 21*	1994	Grain crops (13 years), sugar beet (1), corn (2), perennial grasses (2), annual grasses (1), complete fallow (1)	34.1	23.5	24.0	81.6
Romodanovsky, Maloe Chufarovo village, 22	1994	Grain crops (13 years), complete fallow (3), perennial grasses (3), corn (1 year)	23.1	15.8	12.7	51.6

Note: * at RP 21, manure was introduced in 1997 for winter wheat at a dose of 40 t/ha

Soil sampling was carried out annually in spring before the start of fieldwork. Samples were taken to the depth of the arable layer. The following studies were carried out in soil samples: humus content according to State Standard (GOST) 26213–91 by the Tyurin method with a photometric end; pHkcl with preparation of a salt extract and determination by the Central Research Institute of Agrochemical Services for Agriculture (CINAO) method (GOST 26483-85), mobile phosphorus and potassium content by the Kirsanov method in the CINAO modification with a photometric end (GOST 26207-91); potassium content by flame photometric method (GOST 30504–97) (Kargin et al., 2017; Ivanova et al., 2019; Solodovnikov & Levkina, 2020).

RESULTS AND DISCUSSION

1994-1998 to 2009-2012 the humus content decreased from 4.0 to 22.8% to the original content (Table 2). The greatest decrease was noted on leached chernozems of RP 5 and 21, where in the 80s and 90s high doses of organic fertilizers had been applied. The trend of changes in humus in the arable layer indicates that in the arable layer of the studied soils there is a decrease in the content of soil organic matter. Trends in the change in the percentage of humus indicate a decrease in the content of humus in all RPs:

$Y = 9.61–0.1•X$ (RP 5);
$Y = 8.0–0.05•X$ (RP 8);
$Y = 8.69–0.04•X$ (12);
$Y = 12.38–0.22•X$ (RP 21);
$Y = 7.69–0.05•X$ (RP 22);

During the study period, there was slight acidification of the reaction of the soil solution. The negative trend in the change in the reaction of the soil solution remained until the end of the observations. The increase in acidity can largely be associated with infiltration losses of exchange bases and the absence of liming during the years of observation. The differences between individual sites are relatively small between different sites in terms of pHsol.

Table 2. Humus content, the reaction of soil solution, phosphorus, potassium, 1994–2012.

Indicators	Years of observations	RP numbers				
		5	8	12	21	22
Humus content, %	1994–1998	7.9–9.6	7.3–8.2	7.65–9.0	10.4–11.48	6.9–8.4
		9.04±0.30	7.68±0.16	8.45±0.24	11.12±0.2	7.62±0.25
	1999–2003	9.0–9.9	5.8–6.1	8.2–9.3	10.4–12.7	7.2–7.8
		9.34±0.15	5.9±0.05	8.84±0.21	11.36±0.37	7.58±0.12
	2004–2008	7.2–9.2	5.86–6.6	7.3–8.3	6.9–10.2	6.4–6.8
		8.46±0.42	9.04±0.23	7.75±0.24	8.28±0.66	6.62±0.09
	2009–2012	6.1–8.5	6.00–7.1	7.1–8.4	7.1–9.40	5.8–8.0
		7.65±0.53	6.72±0.25	7.87±0.29	8.58±0.51	7.0±0.46
	1994–2012	6.1–9.9	6.0–8.4	7.1–9.3	6.9–12.7	5.8–8.40
		8.67±0.22	7.46±0.14	8.27±0.15	9.9±0.40	7.22±0.15
The reaction of the soil solution pHsol	1994–1998	5.3–6.7	5.8–7.5	5.6–7.2	7.1–8.3	5.4–6.9
		6.1+0.3	6.5+0.4	6.1+0.3	7.6+0.2	6.3+0.3
	1999–2003	5.3–7.2	5.8–6.1	6.7–6.9	7.1–7.4	5.3–5.6
		6.2+0.4	5.9+0.05	6.8+0.04	7.2+0.06	5.4+0.05
	2004–2008	5.1–5.6	5.5–6.6	5.5–5.8	6.8–7.2	5.2–5.7
		5.3+0.1	5.9+0.3	5.6+0.07	7.0+0.08	5.5+0.09
	2009–2012	5.9–6.4	5.5–6.0	5.5–6.0	5.1–6.8	5.5–6.9
		6.1±0.12	5.8±0.12	5.7±0.11	6.3±0.41	5.9±0.34
	1994–2012	5.2–7.2	5.5–7.5	5.5–7.2	5.1–8.3	5.2–6.9
		5.95±0.14	6.1±0.14	6.1±0.14	7.1±0.15	5.8±0.13
P_2O_5, mg/kg of soil	1994–1998	225–349	205–239	110–204	209–260	97–153
		259.2+23.3	227+6.36	153.4+17.7	237.6+8.9	125.2+9.2
	1999–2003	202–595	211–309	162–227	276–391	107–132
		353.2+68.7	254+16.5	197.6+13.0	305.0+22.1	121.4.5
	2004–2008	182–443	225–339	210–260	306–470	113–213
		313.4+46.7	258.8+22.7	232.7+10.5	408.4+35.6	165.4+20.2
	2009–2012	202–364	230–380	233–431	378–507	124–179
		252.0+38	310.0+31	325.5+43.6	435+30	154.8+11.6
	1994–2012	182–595	205–380	110–431	209–507	97–213
		292.9±25.2	262.9±11	221.6±18.4	342.6±22.0	141.1±7.41
K_2O, mg/kg of soil	1994–1998	128–236	212–354	117–164	262–449	163–210
		184.0+18.6	285.4+27.4	117–164	327.2+31.8	188.6+7.9
	1999–2003	126–306	197–286	108–181	324–541	122–204
		211.0+33.3	237+14.9	139.4+12.8	420+49.0	160.6+13.3
	2004–2008	114–174	229–279	142–168	482–558	138–239
		142.8+9.9	243.4+9.3	155.7+6.8	514.2+12.3	191+20.4
	2009–2012	127–190	170–374	158–217	336–985	142–220
		165+13	279+51	178+13.2	657+169	175+17.3
	1994–2012	114–306	170–374	108–217	262–985	122–239
		176.4±12.2	260±13	151.5±6.4	470.3±44.5	178±7.59

Note: the numerator is the oscillation interval, the denominator is the arithmetic mean + average deviation

Cultivated chernozems (RP 8, 12, 21) are characterized by an increased content of phosphorus and potassium. The farms where these soils are located function on intensive farming. Mineral fertilizers are annually applied to the crops growing in these areas, so the fertility of the soil does not decrease. RP No. 21 has had a high content of phosphorus and potassium at approximately the same high level (461 and 336 mg/kg) for a long period of observations, which can be explained by the high content of natural fertility (leached chernozems, with a humus content of 8.7%, the use of fertilizers and protective equipment). On the same benchmark, the pH value of 6.8 practically has not changed from year to year, which can be explained by the fact that the plot is located near a process plant (a cement plant of Mordovcement OJSC) and during the production process of the plant cement dust settles on the soil, neutralizing soil acidity.

The maximum amount of mobile phosphorus was observed on average over the years of the study. This indicates that only in the Oktyabrsky district (RP 5) its content was at the same level. In all other areas, there was an increase in this indicator. It is known that the content of potassium in soils depends primarily on their mineralogical and granulometric composition. The minimum content of potassium was found in the soils of Cheremishevskoye LLC of the Lyambirsky region, and the maximum content was observed at Saburmachkasskoye LLC of the Chamzinsky region.

Summing up, we can conclude that the evolution of the properties of chernozem soils as a result of their long-term agricultural use is determined by the balance of the production and cultural soil-forming process. Therefore, continuous monitoring is an integral part of national control. Its significance increases even more in the conditions of active agro-technological impact. During the 1994-2012 observations, the humus content in the arable layer decreased by 4.0-22.8% to the original content. The greatest decrease was noted on leached chernozems of RP 5 and 21, where in the 80s and 90s high doses of organic fertilizers had been applied. The trend of changes in humus in the arable layer indicates that in the arable layer of the studied soils there is a decrease in the content of soil organic matter. The reaction of the soil solution in 1994–2012 indicates that in all RPs a decrease in this indicator can be noted. The negative trend in the change in the reaction of the soil solution remained until the end of the observations. The increase in acidity can largely be associated with infiltration losses of exchange bases and the absence of liming during the years of observation. The differences between individual plots are relatively small (Solodovnikov & Levkina, 2020).

In the arable layer of RPs, except for RP 5, an increase in mobile phosphorus was observed. The potassium content is lower than the phosphorus content. Its high content against the background of a negative balance is obvious since high doses of phosphorus fertilizers have been used for a long time (70–80s of the last century). This made it possible to form a reserve fund of this element, which still maintains the content of its mobile forms at a very high level. There was a decrease in the level of mobile phosphorus, while its increase in the upper ones in the process of agricultural use in the lower layers of the soil profile. We have found a significant (r = 0.72) relationship between the content of mobile phosphorus and the accumulation of humus. In our observations, the content of potassium is lower than that of phosphorus, which is associated with much higher mobility and, accordingly, lower ability of potassium to accumulate in the soil, as well as a large removal of this element with the crop. A significant relationship of this indicator with the applied potash fertilizers and humus content was revealed. The concentration of mobile potassium decreases to a depth of 140 cm under conditions of insufficient application of potassium fertilizers, which is associated with the use of potassium by plants from deep layers (Ivanov et al., 2020).

The study showed that against the background of relatively favorable agrochemical characteristics of the arable layer of leached chernozems, there are negative trends associated with dehumification, deterioration of physicochemical characteristics, and a decrease in the content of available forms of nutrients. The degree of development of unfavorable processes is not critical, which is associated with the high buffering capacity of leached chernozems and their resulting stability.

CONCLUSION

The use of soils in agricultural production in recent years has led to a deterioration in their condition, a significant decrease in the content of humus, phosphorus, and potassium in them, which requires constant monitoring of their condition. The importance of soil ecological monitoring is increasing immeasurably, as it allows identifying deviations from optimal indicators to see a retrospective of natural complexes.

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