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ORIGINAL ARTICLE

Changes in enzymatic activity of the arable soil layer under different systems of primary tillage and fertilization of typical chernozem in the short crop rotation of the right-bank forest-steppe zone of Ukraine

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The highest activity of invertase, urease, phosphatase, dehydrogenase and polyphenol oxidase in the arable layer of typical chernozem was observed when applying a moldboard -subsurface tillage in the crop rotation, the lowest-under a shallow disk tillage. The highest protease activity was in the moldboard tillage, peroxidase-in the beardless tillage, and catalase-in the disk tillage, while the lowest correspondent indices were recorded in the permanent shallow (10-12 cm), moldboard and differentiated tillage in the crop rotation. Phosphatase activity of the arable layer did not differ significantly between the beardless and disk tillage. Indices of the peroxidase activity were almost at the same level for the chisel and differentiated tillage. Localization of plant remains and organic fertilizers in the upper soil layer in the beardless and disk tillage leads to the increasing activity of enzymes. The highest coefficient of humus accumulation was recorded in the moldboard-beardless, the lowest-in the disk tillage. Fertilizers raise the soil enzymatic activity. A differentiated system of primary tillage in the crop rotation is recommended, which includes plowing to a depth of 25-27 cm for the sunflower, beardless tillage for the maize and soybeans (25-27 and 16-18 cm, respectively) and shallow (10-12 cm) tillage by a disk harrow for the rest of crops in the rotation. It is proposed to use 12 tons of manure+$N_{95}P_{82}K_{72}$ per one hectare of the arable land.

Keywords: Enzymes; soil; tillage; fertilizers; crop rotation; humus; productivity

Introduction

Scientists convincingly prove the need of integrated monitoring of agricultural landscapes of Ukraine by indices of the soil enzymatic activity, which they consider as an indicator not only of biological parameters of soil fertility, but also of the level of anthropogenic pressure on the national land resources (Dadenko, 2005).

Enzymes are biological catalysts of mineralization and humification of organic matter in the soil environment. Since their source is a soil biota, the enzymatic activity of the soil can be used to draw conclusions about the intensity and direction of complex and versatile biochemical processes in the soil (Dobrovolsky, 2006).

The enzymatic activity of soils is an important factor of the formation of quantitative and qualitative humus indices. The changes are manifested by the involvement of virgin chernozem soils in an agricultural process or by the application of various techniques of their use. First and foremost, it has an impact on the biodegradation processes of fresh organic matter and on the participation in the formation of structural elements of humus substances, thereby defining the composition of organic matter in the soil (Bayer et al., 2002). The transformation of the humus composition determines a macroscopic structural arrangement that, in turn, determines functional abilities of humus substances to accumulate and support migration of various elements in the ecosystem (Orlov, 1990; Piccolo, 2002).

After the death of soil biota, the enzymes, included in its structure, are mainly sorbed by silty and colloid fractions of the soil, concentrating on their surface, and are able to stay active for a sufficiently long period of time. When the soil dispersion increases, the proportion of sorbed enzymes in it also grows which, in contrast to the enzymes of living organisms, represents a relatively stable biological indicator of the fertility of the soil environment. Post-harvest remains of the roots and above-ground parts of plants are also a source of soil enzymes (Kuprevich V.F., 1966).

Hydrolytic enzymes serve as catalysts of the mineralization processes of many organic soil substances. The activity of some of them reflects the intensity and direction of hydrolysis processes of protein and organophosphorus compounds, sugars, cellulose and other intermediate products of the mineralization of plant and animal remains (Khaziev, 1976).

Invertase, a component of the flora and fauna of the soil, is a rather widespread enzyme in the soil environment. Affecting glycosyl compounds, it activates fructotransferase reactions. A catalytic activity of invertase depends on the amount and composition of organic matter in the soil environment. Therefore, researchers of the soil enzymatic activity justify the invertase activity by its presence in dead post-harvest above-ground parts of plants and root remains (Galstian, 1974).

It is known that the activity of catalase and invertase provide scientists with a possibility to compare the intensity of gas exchange between soil and atmosphere and the decomposition of various carbon compounds in the soil environment (Nadtochii, Muslyva & Volvach, 2010).

According to experts, the biological soil activity is evaluated by the activity of enzymes, microorganisms and the intensity of carbon dioxide production by the soil environment (Prymak et al., 2014).

A high enzymatic and microbiological activity in the soil environment can cause an excessive mineralization of organic matter, in particular humus, and, consequently, result in the unproductive losses of nitrogen and ash nutrition elements of plants (Prymak, Panchenko & Panchenko, 2017).

It should be noted that there is a limited number of studies, discussing the influence of mechanical tillage on the enzymatic activity of soils in Ukraine, and their results are often contradictory. Most national scientists indicate that more favourable enzymatic activity of typical chernozem is promoted by the application of deep tillage in the rotation once in 4-5 years, especially if adding organic fertilizers for the cultivated crops. In the period between the tillage they offer surface, shallow, disk, chisel or subsurface cultivation (Tsiuk, 2013; Panchenko, 2016).

A number of scientists stresses that only permanent surface and beardless tillage of chernozem soils will provide optimal activity of soil enzymes (Petrenko, Andrienko & Ridei, 1998).

Experts of Sokolovskyi Institute of Soil Science and Agrochemistry have found out that the intensive plowing of typical chernozem leads to the change in oxide-reductase activity due to the increase in the biological mineralization and decrease in the humus system stability. The dehydrogenase activity in their experiments increased during tillage because of the release of oxygen-containing functional groups that had been determined by the active mineralization of fresh organic matter (Skrylnyk, Makliuk & Popirnyi, 2017).

The purpose of research was to identify patterns of changes in the soil enzyme activity when applying moldboard, beardless, moldboard-beardless and disk systems of primary tillage and fertilization of the typical chernozem to provide the optimal humus status and crop rotation productivity at the level of 5.5-6.0 t/ha of dry matter.

Materials and methods

The field studies were carried out over the period 2015-2017 in a permanent field experimental plot of Bila Tserkva National Agrarian University. The soil was represented by typical chernozem, light loamy, with low humus content. The experiment was repeated three times; the count area was 112 m^2.

Four variants of primary tillage (Table 1) and four fertilization systems were studied in the crop rotation. Annual levels of fertilizers used per 1 ha of the rotation area were as follows: zero level-without fertilizers, the 1st level-8 t/ha of manure+N76P64K57, the 2nd level-12 t/ha of manure+$N_{95}P_{82}K_{72}$, and the 3d level-16 t/ha of manure+$N_{112}P_{100}K_{86}$.

Table 1. Primary soil tillage systems in the crop rotation.

No of the field	Crop in the rotation	Type of soil tillage*			
		1	2	3	4
		Moldboard tillage (control)	beardless tillage (chisel)	Moldboard-beardless (differentiated)	Disking (permanent, shallow)
		Depth (cm) and tillage techniques			
1	Soybeans	16-18 (t.)	16-18 (ch.)	16-18 (ch.)	10-12 (d.h.)
2	Winter wheat+white mustard for green manure	10-12 (d.h.)	10-12 (ch.)	10-12 (d.h.)	10-12 (d.h.)
3	Sunflower	25-27 (t.)	25-27 (ch.)	25-27 (t.)	10-12 (d.h.)
4	Spring barley+white mustard for green manure	10-12 (d.h.)	10-12 (ch.)	10-12 (d.h.)	10-12 (d.h.)
5	Maize	25-27 (t.)	25-27 (ch.)	25-27 (ch.)	10-12 (d.h)

*Notes: t-tillage, d.h.-disk harrow, ch.-chisel.

The studied soil is represented by typical chernozem, deep, with low humus content, coarse pulverescent light loamy, on carbonated loess. Calcium carbonates occur at a depth of 55-62 cm. The arable soil layer contains near 17% of silty particles and from 46 to 54% of coarse dust; humus (by the method of Turin and Kononova) constitutes 3.4%, weak hydrolyzed nitrogen (by Cornfield's method)-110, movable compounds of phosphorus and potassium (by Chirikov's method)-120 and 110 mg/kg of soil, respectively.

The tillage to a depth of 16-18 and 25-27 cm was provided by a plough PLN 3-35, shallow tillage (10-12 cm) by a heavy disk harrow BDV-3.0, beardless (chisel) tillage-by deep loosener GR-3.4.

Among organic fertilizers, the half-rotted cattle manure on a straw litter was used, mineral fertilizers included ammonia saltpetre, simple granulated superphosphate and potassium chloride. The enzymatic activity of the arable (0-30 cm) soil layer was identified according to standard methods (Khaziev, 2005; Horodnii et al., 2005).

Results and discussion

Identification of soil enzymes, carried out by the authors, reinforces the fact that the invertase activity shows noticeable changes under the influence of different methods, depth and techniques of mechanical tillage of typical chernozem and the application of fertilizers (Table 2).

The systematic shallow tillage for all the crops in the rotation (variant 4), when the remains of roots, above-ground parts of plants and organic fertilizers are localized in the upper part (0-10 cm) of the arable layer of typical chernozem, leads to the increase in the invertase activity by 17-26%, compared with the moldboard primary tillage. In the lower parts (10-20 and 20-30 cm) of the arable soil layer a reverse correlation was recorded: the invertase index was, respectively, 8-16 % and 21-33% higher during the moldboard tillage, in comparison with the disk tillage in the crop rotation.

Similar, but less pronounced, patterns in the invertase activity in different parts (0-10, 10-20, 20-30 cm) of the arable layer of typical chernozem were found in the sites where the system of beardless primary soil tillage had been applied in the crop rotation.

On average, according to the experimental variants in the crop rotation, the invertase activity of the arable soil layer under the chisel and disk tillage was, respectively, 10.5% and 15.6% lower than that in the control. Under the differentiated tillage, this index was 9.8% higher than that for the moldboard tillage.

It was established that the invertase activity of the arable soil layer increased during the vegetation period of cultivated plants from April to August, which was apparently associated with the increase in the root mass of agrophytocoenoses, increase in the temperature and the number of microorganisms.

One of the most common oxidation-reduction enzymes of typical chernozem is catalase, which formation the soil experts associate with the structure of microbial coenosis and the activity of root systems of agrophytocoenoses.

It has been established that the catalase ensures detoxification of cell-destructive hydrogen peroxide. The latter is a product of the breathing process of soil biota and the oxidation of organic substances, which are a leading component of newly formed specific humus compounds (humic acids, fulvic acids and humines) (Khaziev, 1976).

In our experiment, the catalase activity of the arable layer of typical chernozem was, respectively, 7.2% and 9.5% higher in the beardless and disk tillage in the rotation than that in the control. And in sites with the differentiated tillage, this indicator was 8.6% lower than in the variants with the moldboard tillage.

The fertilization norm of 8 tons of manure+$N_{76}P_{64}K_{57}$ per 1 ha of the crop rotation, compared with non-fertilized areas, has averagely increased the activity of invertase and catalase in the experimental variants by 45.1 and 32.9%, correspondingly.

The application of 12 t/ha of manure+$N_{95}P_{82}K_{72}$ has led to the increase in these indices by 19.5% and 22.3%, compared with the sites, fertilized with 8 t/ha of manure+$N_{76}P_{64}K_{57}$. However, the application of 16 t/ha of manure+$N_{112}P_{100}K_{86}$ has raised the invertase and catalase activity of the arable layer only by 9.6% and 15.2%, compared to the variants where 12 t/ha of manure+$N_{95}P_{82}K_{72}$ was applied.

Therefore, the increase in the amount of fertilizers does not provide a direct proportional increase in the activity of these enzymes. It is known that urease can penetrate in the soil with above-ground and root post-harvest remains of plants and organic fertilizers or is formed in the soil environment as an intermediate product of decomposition of organic nitrogen-containing substances. It belongs to a group of amidase enzymes and ensures the urea hydrolysis. The urease activity is considered by scientists as a crucial factor of the soil nitrogen cycle (Petrenko, Andrienko & Ridei, 1998).

In our experiment, this index in the upper part (0-10 cm) of the arable layer was 12.4-21.6% higher in a disk harrow tillage than when applying a plough. Under a systematic soil loosening by chisel this index increased by 6.7-8.8 %, compared with the control. In the middle (10-20 cm) and especially in the low (20-30 cm) parts of the typical chernozem arable layer, the reverse correlation was recorded.

Table 2. Enzyme activity of the arable soil layer under different systems of primary tillage and fertilization in the crop rotation.

Type of soil tillage (factor A)	**Fertilization levels (factor B)**	**Invertase, mg of glucose per 1 g of soil in 24 hrs.**	**Catalase, ml of O_2 per dry soil in 1 min.**	**Urease, mg of N-NO3, per 100 g of soil in 3 hrs.**	**Protease, mg of amine nitrogen per 100 g of soil in 20 hrs.**	**Phosphatase, mg of P_2O_5 per 100 g of soil in 48 hrs.**	**Dehydrogenase, Lenard's units of optical density**	**Polyphenol oxidase Mg of purpurogallin per 100 g of soil in 30 min.**	**Peroxidase**	**Coefficient of humus accumulation**
1	2	3	4	5	6	7	8	9	10	11
Moldboard (control	0	8.06	2.95	2.38	114	0.8	0.123	61	123	49.6
	1	11.23	3.88	3.83	141	1.6	0.181	90	134	67.2
	2	13.38	4.84	4.64	158	2.2	0.268	113	144	78.5

)	3	14.6	5.62	5.25	172	2.6	0.33	135	162	83.3
Beardless (chisel)	0	6.85	3.15	2.19	105	0.6	0.122	62	131	47.3
	1	9.99	4.3	3.59	129	1.3	0.183	92	143	64.3
	2	12.09	5.17	4.42	142	1.9	0.267	111	150	74
	3	13.39	5.89	5.04	154	2.2	0.328	137	175	78.3
Moldboard-beardless (differentiated)	0	9.12	2.72	2.46	108	1	0.132	70	131	53.4
	1	12.43	3.55	4.01	134	1.8	0.199	102	141	72.3
	2	14.69	4.37	4.88	150	2.5	0.299	126	150	84
	3	15.69	5.14	5.56	163	2.9	0.375	150	170	88.2
Disking	0	6.02	3.29	2.16	99	0.6	0.117	57	125	45.6
	1	9.59	4.37	3.55	122	1.4	0.169	84	137	61.3
	2	11.46	5.28	4.38	141	1.8	0.247	106	151	70.2
	3	12.79	5.97	5	145	2.3	0.301	127	171	74.3
HIP0.05	A	0.35	0.06	0.13	3.1	0.2	0.019	4	4	2.3
	B	0.5	0.11	0.17	3.5	0.2	0.028	6	5	3.4
	AB	0.57	0.16	0.21	4.2	0.3	0.034	8	6	4.8

The urease activity of the arable soil layer in unfertilized sites, with the application of 8 t of manure+$N_{76}P_{64}K_{57}$, 12 t of manure+$N_{95}P_{82}K_{72}$, and 16 t of manure+$N_{112}P_{100}K_{86}$ per 1 ha of the arable land of the crop rotation, decreases in the chisel tillage, compared with that in the control, by 8.1; 6.3; 4.8 and 4.0%, correspondingly, and in the disk tillage-by 9.3; 7.3; 5.6 and 4.8%. Therefore, judging from this biological index of soil fertility, the difference between beardless, disk and moldboard tillage was reducing with the increasing level of the applied fertilizers (approximately 2 times reduction when using the highest norm of fertilizers). The urease activity was higher in the regular chisel than in the disk tillage.

The highest urease activity of the arable soil layer as a whole for the crop rotation was recorded in the moldboard-beardless tillage. In the unfertilized sites and with the application of the higher amount of fertilizers than it had been mentioned above, it was, respectively, 3.4; 4.7; 5.2 and 5.9% higher than that in the control. It was also recorded the increase in the agrotechnical effectivity of fertilizers in the differentiated tillage according to this index of the soil enzymatic activity.

The hydrolysis intensity of organic protein-containing substances is evaluated by the activity of proteolytic enzymes. Free amino acids, formed owing to the decomposition of proteins as a result of the protease activity, are subjected to ammoniation and nitrification, thereby causing the formation of mobile forms of the soil nitrogen. In addition, a certain proportion of amino acids takes part in humification of the soil organic matter by means of condensation with oxidized forms of certain aromatic compounds.

The protease activity in the upper (0-10 cm) part of the arable layer of typical chernozem was 12.3 -16.7% higher in the disk tillage, than in the moldboard tillage in the crop rotation. In the chiselling, this index was 8.8-11.8% higher than that in the control.

The protease activity in the lower (20-30 cm) part of the arable soil layer in the chisel and disk tillage, was, respectively, 11.4% and 16.3% lower than in the moldboard tillage.

It was established that the decrease in the tillage intensity of typical chernozem in the crop rotation leads to the decline in the protease activity in the arable soil layer. The highest index was recorded in the moldboard tillage, the lowest-in the disk tillage, where it made up 86.5% compared with that in the control. In the moldboard-beardless and chisel tillage in the crop rotation, this index was, respectively, 5.2 and 9.6% lower than that in the control.

The introduction of 8 tons of manure+$N_{76}P_{64}K_{57}$, 12 tons of manure+$N_{95}P_{82}K_{72}$ and 16 tons of manure+$N_{112}P_{100}K_{86}$ caused, respectively, 23.9; 39.5 and 49.7% increase in the protease activity of the arable soil layer, compared with the unfertilized areas.

Among a wide range of hydrolytic enzymes, which activity determines the amount and forms of available nutrition elements for agricultural crops, soil phosphatases are of great importance. Their direct involvement in the decomposition of plant and animal remains ensures the formation of the organic substances, which have phosphorus in their structure. In particular, they are carbohydrate esters, organic acids, lipids, specific humus compounds, phytin, etc, which further hydrolysis produces the orthophosphoric acid available to cultivated plants (Maltseva et al., 2005).

The highest phosphatase activity of the arable soil layer, as a whole for the crop rotation, was recorded in the differentiated tillage, where this index exceeded the control by almost 15%. In the case of disk and chisel tillage, the phosphatase activity was, correspondingly, 16.2% and 17.6% lower.

The influx of the main part of plant remains and organic fertilizers to the upper (0-10 cm) part of the arable soil layer, as observed in the chisel and disk tillage in the crop rotation, increases the phosphatase activity in it by 26.1 and 32.3%, respectively, if compared with the moldboard tillage.

In order to study the direction and intensity of oxidation processes in plant and animal remains within a general framework of the cultivated soil formation, it is first of all necessary to investigate the activity of oxidation-reduction soil enzymes, in

particular, dehydrogenases, which catalyse dehydrogenation processes (reactions of splitting hydrogen out of organic soil substances) and are intermediate carriers of hydrogen. In the soil environment there is a fairly diverse spectrum of dehydrogenation substrates, in particular, humic acids, carbohydrates, amino acids, alcohols, aromatic acids, etc. (Dobrovolsky & Nikitin, 2006; Kuprevich & Sherbakova, 1966).
A sufficiently high dehydrogenase activity in the soil is observed in respect to carbohydrates and organic acids. Hydrogen, formed due to the dehydrogenation, is usually transferred to atmospheric oxygen or organic compounds such as xenons. The oxidation of organic acids and carbohydrates are observed under the mineralization and humification processes of plant and animal remains in the soil environment (Nadtochii, Myslyva & Volvach, 2010).
The dehydrogenase activity of the soil directly depends on the available content of the oxidation substrate, found in plant and animal remains. In this respect, according to scientists, the dehydrogenase activity is a fairly reliable indicator of the content of plant remains in different parts of the arable soil layer (Dadenko, 2005; Khaziev, 1976). This has been also convincingly proved by the results of our research.
When applying the permanent chisel and disk tillage in the crop rotation, the dehydrogenase activity of the upper (0-10 cm) part of the arable soil layer was, respectively, 16-22% and 24-29% higher, whereas that of the lower part (20-30 cm) was 18-26% and 25-34% lower than in the control. It was associated with the localization of organic remains during the plowing without turning over the tilled layer of typical chernozem.
Generally, in the crop rotation, this index in the arable layer was similar in the moldboard and beardless tillage.
The highest dehydrogenase activity in the arable soil layer was observed in the differentiated, the lowest-in the disk tillage, compared with that in the control. It has been found out that increasing norms of fertilizers intensify the difference in the activity indices of this enzyme between the mentioned tillage techniques and the control. Thus, in the unfertilized sites, with the application of 8 t/ha of manure+$N_{76}P_{64}K_{57}$, 12 t/ha of manure+$N_{95}P_{82}K_{72}$ and 16 t/ha of manure+$N_{112}P_{100}K_{86}$, the difference between the differentiated and moldboard tillage was, respectively, 7.1; 9.8; 11.4 and 13.5%, and between the disk and moldboard tillage-4.8; 6.5; 7.7 and 8.7%.
It should be noted that for the beardless and disk tillage in the rotation, the differentiation of the arable layer of typical chernozem by dehydrogenase activity has a relatively constant pattern. The highest activity of this enzyme is observed in June, and the lowest is in April and October.
Humification of organic matter of the soil is inseparably linked with the decomposition processes of plant remains. Polyphenol oxidases take an active part in the processes of transformation of organic compounds of the aromatic series into the components of the soil humus substances. They conduct catalytic oxidation of phenols to quinones in the presence of atmospheric oxygen. Therefore, their highest activity is observed in the upper layers of the tilled soil.
A great number of scientists assume that aerobic processes occur in the upper layers of the soil, and anaerobic-in the lower layers (Shikula & Nazarenko, 1990). However, not all the researchers agree with the conclusion that the aerobic and anaerobic conditions can be found within the arable layer (Grechin, 1970).
The scientists associate the formation of primary molecules of humic acids with quinones, which are a result of the condensation with amino acids and peptides.
A majority of the experts make a simultaneous evaluation of the activity of polyphenol oxidase and peroxidase. It is due to the fact that the peroxidase oxidises organic soil compounds, in particular, phenols, amines and some heterocyclic substances at the expense of the oxygen, containing in hydrogen peroxide and organic peroxides, which in turn, are a result of the life activity of soil biota and actions of some oxides. The scientists have proved a great importance of the peroxidase in the reactions, determining the intensity of mineralization processes of humus substances of the soil. On the basis of this understanding, the researchers propose to evaluate the intensity of soil humus accumulation by the ratio of the activity of these two enzymes (polyphenol oxidase and peroxidase) calling it the humus accumulation coefficient (Kuprevich & Sherbakova, 1966).
The polyphenol oxidase activity of the typical chernozem arable layer was almost identical in the moldboard and chisel tillage in the crop rotation. On average, in the experimental variants, this index in the moldboard-beardless tillage was 12.3% higher, and in the disk tillage-6.4% lower than that in the control.
The peroxidase activity in the disk, differentiated and the chisel tillage in the crop rotation was, relatively, 3.7; 5.2 and 6.4% higher than that in the control. A significant increase of the polyphenol oxidase activity in the upper soil layer (0-10 cm) was recorded in the beardless and especially disk tillage. In the middle (10-20 cm) and lower (20-30 cm) parts of the arable layer, this index was higher in the sites with the differentiated tillage, where the importance of this enzyme in humus-forming processes grows because of the reduced peroxidase activity and increased humus accumulation coefficients.
In case if the lower parts of the arable layer have relatively anaerobic conditions, the decay of vegetation remains will be accompanied by a retarded oxidation of polyphenols under the effect of peroxidase. The latter uses the oxygen of hydrogen and peroxide compounds, in contrast to the polyphenol oxidase, which consumes the oxygen of the ground air.
Since, as it has been mentioned above, peroxidase is an agent of the mineralization of the soil humus substances, and since the moldboard-beardless tillage (compared with chisel and especially disk tillage) causes an increase in both polyphenol oxidase and protease activity of the typical chernozem arable layer, then it is logical to expect that it is a differentiated tillage in the crop rotation where the increase in the intensity of humus formation will be manifested.
In the unfertilised sites, when using 8 t/ha of manure+$N_{76}P_{64}K_{57}$, 12 t/ha of manure+$N_{95}P_{82}K_{72}$, and 16 t/ha of manure+$N_{112}P_{100}K_{86}$, the humus accumulation coefficient decreased in the beardless tillage, compared with the moldboard, by 4.1; 4.5; 5.1 and 6.0%, respectively; in the disk tillage-8.2; 9.0; 10.3; and 10.8%. In the moldboard-beardless tillage this index increased by 8.2; 7.5; 7.7 and 6.0 %, respectively, compared with that in the control.
When applying the above-mentioned norms of fertilizers, the polyphenol oxidase activity increased by 48.0; 83.7 and 121.6 %,

respectively, the peroxidase activity-by 8.9; 16.8 and 33.2%, and the humus accumulation coefficient increased by 36.1; 57.7 and 66.5%, respectively, in comparison with the unfertilized variants.

A significant increase in the density of decinormal alkaline extraction from typical chernozem, which we have recorded in the moldboard-beardless system of primary tillage in the rotation, indicates the faster rate of new formation of mobile humic acids. In our view, it is connected with more optimal distribution of introduced fertilizes in the arable layer and available remains of vegetation mixed with the soil that ensure intensive activity of microbiota in relation to humus development in the soil environment.

The productivity of crop rotation was almost the same in the moldboard and differentiated soil tillage. A noticeable decrease in this productivity was recorded in the beardless and disk tillage, compared with the moldboard one. Thus, the harvest of dry substance (grain, seeds, straw of wheat and barley), forage units and yield of digestible protein per 1 ha of the arable land on average for the experiment variants were, respectively, as follows: in the moldboard tillage-4.73; 4.83 and 0.40 t; in the beardless tillage-4.21; 4.27 and 0.35 t; in the moldboard-beardless-4.72; 4.84 and 0.40 t; in the disk tillage-4.34; 4.46 i 0.36 t with HIP0.05 equalling 0.28; 0.33; and 0.02 t/ha, correspondingly. Therefore, the above-mentioned indices of the crop rotation productivity were lower in the disk tillage by 8.2; 7.7 and 10.0%, correspondingly; in the beardless tillage-by 11.0; 11.6 and 12.5% compared to those in the control.

The highest indices of profitability and energetic efficiency coefficient in all the variants of primary tillage in the rotation were obtained by using 12 t/ha of manure+$N_{95}P_{82}K_{72}$ per 1 ha of the arable land.

Conclusion

Localization of plant remains and organic fertilizers in the upper soil layer in the beardless and disk tillage leads to the increasing activity of enzymes. The highest coefficient of humus accumulation was recorded in the moldboard-beardless, the lowest-in the disk tillage. Fertilizers raise the soil enzymatic activity. A differentiated system of primary tillage in the crop rotation is recommended, which includes plowing to a depth of 25-27 cm for the sunflower, beardless tillage for the maize and soybeans (25-27 and 16-18 cm, respectively) and shallow (10-12 cm) tillage by a disk harrow for the rest of crops in the rotation. It is proposed to use 12 tons of manure+N95P82K72 per one hectare of the arable land.

References

Dadenko, E. V. (2005). Some methodical aspects of the application of enzymatic activity indices in the diagnostics and monitoring of soils. Abstracts of reports of the international scientific conference “Ecology and Biology of Soils”- Rostov-on-Don, pp: 143-147.

Dobrovolsky, G. V., & Nikitin, E. D. (2006). Ecology of soils. Moscow State University Press, 476 p.

Bayer, C., Martin-Neto, L., Mielniczuk J (2002). Tillage and cropping system effects on soil humic acid characteristics as determined by electron spin resonance and fluorescence spetroscopies. Geoderma, 105, 81-92.

Orlov, D. S. (1990). Humic acids of soils and general humification theory. Moscow State University Press, 325 p.

Piccolo, A. (2002). The supramolecular structure of humic substances. A novel understanding of humus chemistry and application in Soil Science. Advances in Agronomy, 75, 57-133.

Kuprevich, V. F., & Sherbakova, T. D. (1966). Soil enzymology. Nauka i Technika, 276 p.

Khaziev, F. Kh. (1976). Soil enzymatic activity. Moscow: Nauka, 179 p.

Galstian, A. Sh. (1974). Enzymatic activity of soils of Armenia, 174 p.

Nadtochii, P. P., Myslyva, T. M., & Volvach, F. V. (2010). Soil ecology: Monograph, 473 p.

Prymak, I. D. & Riaba, O. I. (2014). Theoretical bases of contemporary agriculture, 525 p.

Prymak, I. D., Panchenko, O. B., & Panchenko, I. A. (2017). Enzyme activity of typical chernozem when applying different systems of tillage and fertilization of crops in the specialized tilled crop rotation. Bulletin of Lviv National Agrarian University, 21, 30-37.

Tsiuk, O. A. (2013). The theoretical rationale and development of the ecological farming system in the forest-steppe zone of Ukraine: abstract of the dissertation for a degree of the Candidate of Agricultural Sciences: spec. 06.01.01 “General Farming”, 41 p.

Panchenko, O. B. (2016). Restoration of soil fertility of typical chernozem depending on the systems of primary tillage and fertilization in the tilled crop rotation of the Right-bank forest-steppe zone of Ukraine: abstract of the dissertation for a degree of the Candidate of Agricultural Sciences: spec. 06.01.01 “General Faming”, 22 p.

Petrenko, L. R., Andrienko, V. A., & Ridei, N. M. (1998). Changes in soil biological properties when applying tillage without turning over the soil layer. Restoration of soil fertility in soil-protective agriculture, pp: 122-144.

Skrylnyk, E. V., Makliuk, O. I., & Popirnyi, M. A. (2017). Impact of enzymatic activity of typical chernozem on the composition and hydrophobic-hydrophilic properties of humic acids when using different types of tillage. Bulletin of Agrarian Sciences, 5, 11-16.

Khaziev, F. Kh. (2005). Methods of soil enzymology, 252 p.

Horodnii, M. M., Lisoval, A. P., & Bykin A. V. (2005). Agrochemical analysis: Textbook, 262-272.

Maltseva, N. N., Davydova, O. E., Kots, S. Y., Gaevski, A. P., Aksilenko, M. D., & Derevianko, K. U. (2005). Phosphatase activity of rhizosphere and roots of cultivated plants when applying new complex preparations. Physiology and Biochemistry of Cultivated Plants, 37(5), 443-451.

Shikula, N. K., & Nazarenko, V. G. (1990). Minimum tillage of black soils and restoration of their fertility, 320 p.

Grechin, I. P. (1970). Some results and further objectives in the research of oxygen soil regime. Bulletin of Timiryazev Agricultural Academy, 1, 103-110.

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