Influence of the main tillage on the enzymatic activity of ordinary chernozem

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Abstract. Soil fertility is largely determined by the intensity and direction of enzymatic reactions. All biological processes associated with the transformation of substances and energy in the soil are carried out with the help of enzymes that play an important role in the mobilization of plant nutrients, and also determine the intensity and direction of the most important biochemical processes associated with the synthesis and decomposition of humus, hydrolysis of organic compounds and oxidative - the restorative regime of the soil, therefore, the enzymatic activity of the soil can be used as a diagnostic indicator of soil fertility under various types of anthropogenic load. The influence of the methods of basic soil cultivation on the enzymatic activity of ordinary chernozem in winter wheat crops during its cultivation on a pure and green manure fallow in the conditions of the Middle Volga region has been studied.

According to the results of the studies, the highest catalytic activity of ordinary chernozem in winter wheat crops for the studied enzymes (urease, invertase, catalase, peroxidase and polyphenol oxidase) is confined to the 0-20 cm layer and is explained by the abundant location in it of the "living" root mass enriching the upper soil layer biologically active exudates that stimulate the development of microflora and activate enzymatic activity. Favorable conditions for the humification of plant residues and the accumulation of humus-like substances are formed when green manure fallow is included in the crop rotation and used as the main soil cultivation without loosening by 10-12 cm.

1. Introduction

Intensive agriculture of the 20th century, which was based on theoretical principles that did not pay due attention to the principles of environmental sustainability and environmental protection, led to the fact that over the past 100 years, humanity has lost half (2 billion hectares) of fertile land. Annual losses due to erosion amount to 6-7 million hectares [1,2,3,4,5,6,7]. Degradation processes have embraced even such ecologically sustainable soils as chernozems, which are a reference example of self-replicating fertility. One of the priority principles of modern agriculture, as a branch of agricultural production, is resource conservation, which makes it possible to significantly reduce the cost of production and, accordingly, increase the profitability and competitiveness of the industry. However, in addition to resource conservation, an important task in agriculture is the preservation of soil fertility.
Microorganisms are a key factor in the soil formation process, the cycle of nutrients and self-cleaning of the soil. Their interaction with the plant plays a decisive role in plant nutrition and the productivity of agrophytocenosis. Thus, to maintain and reproduce fertility, dynamic control over the state of soil microflora is necessary. Among the known methods for diagnosing anthropogenic changes in the biological properties of the soil, the most promising is the method based on the determination of the enzymatic activity of the soil. Its advantage is the ability to determine changes in the soil at early stages and the ability to predict the direction of soil processes [2,8]. In connection with the above, the goal of our research was to study the enzymatic activity of ordinary chernozem, depending on the methods of basic soil cultivation.

2. Objects, conditions and methods.
The studies were carried out in 2016-2018. on the basis of the stationary experience of the Department of Agriculture, Soil Science, Agrochemistry of the Samara State Agrarian University in the crops of winter wheat, which was cultivated in a crop rotation with the following crop rotation:

1) clean fallow/green manure fallow;
2) winter wheat;
3) soy;
4) spring wheat;
5) barley.

The soil of the site is ordinary heavy loamy medium humus medium thick chernozem. The experimental design included three options for basic soil cultivation:

1. Plowing 20-22 cm;
2. Loosening by 10-12 cm;
3. No-till technology

The catalase activity of the soil was determined by the method of R.S. Kantselson and V.V. Ershov and were calculated in μmol H₂O₂ (decomposed)/min/g soil. The urease activity of the soil was determined by the method of I.N. Romeiko and S.M. Malinskaya, was calculated in μmol NH₄⁺ (formed)/min/g soil. The invertase activity of the soil was determined by the method of A. Sh. Galstyan. The activity of the enzymes peroxidase and polyphenoloxidase was determined by the method of A. Sh. Galtyan, A. I. Chunderova and expressed in mg of purpur gallin per 1 g of soil [9].

3. Research results
The activity of soil enzymes, depending on the methods of the main tillage in winter wheat crops, are presented in table 1, it directly relates to the conversion of carbon, nitrogen and redox processes, which means it characterizes the functional state of soil microorganisms.

Table 1. Enzymatic activity of ordinary chernozem, depending on the methods of basic soil cultivation.

| Tillage | Soil layer, cm | Invertase, μmol glucose/min/g soil | Ureaza, μmol NH₄⁺/min/g soil | Catalase, μmol H₂O₂/min/g soil | Polyphenol oxidase, mg purpur gallin/g soil | Peroxidase, mg purpur gallin/g soil | Humification coefficient |
|---------|----------------|-----------------------------------|-----------------------------|-------------------------------|---------------------------------|----------------------------------|-------------------------|
| Plowing | 0-5            | 0.93                              | 0.089                       | 10.82                         | 0.819                           | 1.628                            | 0.503                   |
|         | 5-10           | 0.79                              | 0.069                       | 11.43                         | 1.013                           | 1.255                            | 0.807                   |
|         | 10-20          | 0.88                              | 0.071                       | 11.26                         | 1.191                           | 1.342                            | 0.887                   |
|         | 20-30          | 0.82                              | 0.068                       | 10.68                         | 1.067                           | 1.709                            | 0.624                   |
|         | 0-30           | 0.86                              | 0.074                       | 11.05                         | 1.023                           | 1.484                            | 0.689                   |
| Loosening | 0-5            | 0.72                              | 0.087                       | 11.42                         | 1.141                           | 1.400                            | 0.815                   |
|         | 5-10           | 0.81                              | 0.085                       | 11.64                         | 1.236                           | 1.227                            | 1.007                   |
|         | 10-20          | 0.84                              | 0.072                       | 11.14                         | 1.434                           | 1.286                            | 1.115                   |
To identify the features of nitrogen metabolism, we studied the enzyme urease (carbamid-amidohydrolase), the action of which is associated with the processes of hydrolysis and conversion into an accessible form of urea nitrogen. The latter can be formed in significant quantities in soils when plant residues are introduced as intermediate products of the metabolism of organo-nitrogen compounds, especially nitrogenous bases of nucleic acids [10]. Many researchers consider urease activity as an indicator of the self-cleaning ability of soil contaminated with organic xenobitics. The action of urease is associated with the hydrolytic cleavage of the bond between nitrogen and carbon (CO\(_2\)) in the molecules of nitrogen-containing organic compounds. In agroecosystems, a rapid increase in urease activity also indicates the ability to accumulate ammonia nitrogen in the soil. Therefore, many researchers have noted a positive correlation between the activity of urease and the content of nitrogen and humus in soils [11, 12].

The research results showed that in the variants where pure fallow was the precursor of winter wheat, tillage did not have a significant effect on the activity of the urease enzyme. Its activity is the same on average over the 0-30 cm layer and is 0.075 μmol NH\(_4\)/min/g soil. In the variant with plowing, a uniform distribution of the enzyme over the arable soil horizon is observed.

With a decrease in the mechanical load on the soil (non-loosening, no-till technology), the activity of the enzyme increases in the upper soil layer of 0-10 cm and its activity decreases with increasing depth.

In the variants of the experiment, where green manure was the precursor of winter wheat, an increase in the urease activity of the soil was noted. This is especially noticeable in the variant with plowing of the soil: the activity of the enzyme was 1.5 times higher in comparison with the placement of winter wheat in pure fallow, which indicates a high level of nitrogen exchange in the soil.

The introduction of green manure fallow into the crop rotation in the options of non-loosening and without autumn mechanical tillage (no-till technology) caused a slight increase in the activity of the enzyme in the arable soil horizon, its highest content was noted in the 0-10 cm layer with non-loosening and in the 0-5 layer. see when applying no-till technology.

The most important link in the carbon cycle in nature is the stage of enzymatic conversion of carbohydrates in the soil environment. It ensures the movement of huge amounts of organic material entering the soil and the energy accumulated in it, as well as its accumulation in the soil in the form of humus, since in this case pre-humus components are formed [9, 13].
Plant residues entering the soil are 60% carbohydrates. Mono-, di- and polysaccharides (cellulose, hemicellulose, starch, etc.) are found in the soil. It is obvious that agroecological influences, leading to a change in the physicochemical and biological state of soils, affect the activity of enzymes of carbohydrate metabolism. Invertase (β-D-Fructofuranoside-fructohydrolase, sucrase) is one of the most active enzymes in the soil of the glucoside hydrolase group, which catalyzes the hydrolysis of di-, tri- and polysaccharides by glucosidic bonds in their molecules, and also triggers other fructotransferase reactions. Invertase is involved in the biochemical transformations of carbohydrates, which are found in significant quantities in soil organic matter, microorganisms, and plants [14].

Studies have shown that plowing promoted a fairly uniform distribution of the enzyme in the 0-30 cm layer, from 0.93 μmol glucose/min/g soil in the 0-5 cm layer to 0.82 μmol glucose/min/g soil in layer 20-30 cm. In the variant with non-loosening of the soil, there is a decrease in the amount of enzyme in the 0-5 cm layer (1.3 times compared with plowing). When using the no-till technology, the invertase activity in the 0-5 cm layer was at the level of plowing, and in the underlying layers, this indicator was at the level of 0.68-0.62 μmol glucose/min/g soil, which indicates a low content there easily hydrolyzable organic carbon.

According to the background of green manure fallow, on average, according to the variants of the experiment, an increase in the activity of invertase in the arable layer of soil by 1.5 times was noted. According to the options for the main soil cultivation, no clear patterns were found in the 0-30 cm layer; there is an increase in the enzyme activity in the upper soil layers of 0-20 cm.

Considering the enzymatic activity of soils, attention should be paid to the oxidation of the products of hydrolysis of organic compounds with the formation of pre-humic substances. These reactions take place with the participation of oxidoreductases, an important representative of which is catalase. Catalase is a widespread enzyme inherent, with rare exceptions, to all living organisms. In some bacteria, its amount is about 1% of the dry matter of the cell. As a result of its activating action, hydrogen peroxide, toxic to living organisms, is split into water and free oxygen.

Studies have shown that when winter wheat is placed in a crop rotation after clean fallow, the tillage option does not affect its catalase activity. A uniform distribution of the enzyme over the plow horizon of the soil was noted, regardless of the method of its processing.

The introduction of green manure fallow into the crop rotation caused an increase in the catalase activity of the soil in all studied variants of the experiment, which indicates an increase in oxidative processes in the soil.

Determination of the activity of polyphenol oxidase and peroxidase involved in the processes of humus formation is a characteristic of the processes of synthesis and decay of humic substances. Peroxidase is an enzyme that oxidizes soil organic matter due to atmospheric oxygen and hydrogen peroxide; its influence is directed to the oxidation of humic substances. Polyphenol oxidase is an enzyme involved in the conversion of organic compounds of the aromatic series into humus components [15, 16].

Peroxidase and polyphenol oxidase are the main agents for the humification of lignins, which make up 15-30% of the dry matter of plant residues entering the soil. Determination of polyphenol oxidase activity on winter wheat crops, where pure fallow was the precursor, showed that the highest enzyme activity was observed in the variants with non-loosening of the soil and no-till technology (1.209 and 1.131 mg of purpurrgallin/g soil, respectively). The indices of the activity of the enzyme polyphenol oxidase in the background of green manure steam are higher than in the background of pure steam, and according to the methods of the main tillage, the non-loosening by 10-12 cm had a positive effect.

The peroxidase activity of the soil was also higher in the background of green manure fallow, the highest activity of the enzyme was noted in the plowing -1.484 mg purpurrgallin/g soil. For the options of pure steam, no dependence of this indicator on the option of the main tillage was noted.

According to a number of scientists [17, 18], the ratio of the activity of polyphenol oxidase and peroxide sidase can be used as a coefficient of humification (Kr), and its value is over 1 indicates the predominance of humus formation processes over its mineralization.
The values of this coefficient obtained in our studies indicate favorable conditions for the humification of plant residues and the accumulation of humus-like substances when green manure fallow is included in the crop rotation; for this background, the humification coefficient ranges from 1.198 for the plowing option to 1.251 for the no-till technology, for the non-loosening option the highest values were obtained - 1.462.

4. Conclusion
The study of the enzymatic activity of ordinary chernozem, depending on the methods of basic tillage against the background of pure and green manure fallow, showed that the highest catalytic activity of ordinary chernozem in winter wheat crops for the studied enzymes is confined to the 0-20 cm layer and is explained by the abundant location of the "live" root masses enriching the upper soil layer with biologically active exudates, stimulating the development of microflora and activating enzymatic activity.

Variants of basic tillage did not have a significant effect on the activity of enzymes in terms of the background of pure steam.

Sideral fallow had a stimulating effect on the activity of the studied soil enzymes. For this background, the highest values of invertase activity were observed during plowing - 1.15 μmol glucose/min/g soil, urease - after plowing and less loosening (0.088 and 0.085 μmol NH₄ +/min/g soil, respectively), catalase, polyphenol oxidase and peroxidase was 10-12 cm higher according to the non-loosening option.

Favorable conditions for the humification of plant residues and the accumulation of humus-like substances are formed when green manure fallow is included in the crop rotation and used as the main soil cultivation by non-loosening by 10-12 cm.

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