Application of Fertilizers and Change of Enzymatic Activity of Soils

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Abstract

As a result of experimental research it has been found that piedmont irrigated chestnut soils of Zailiyskiy Alatau in natural conditions are characterized by moderate activity of hydrolytic and redox enzymes.

Crop rotation raises hydrolytic activity of enzymes' groups (invertase, urease, ATPase) by 30% in comparison with monoculture, but at the same time it does not have a significant impact on change of biological activity of redox enzymes (catalase, dehydrogenase).

Hydrolytic activity of soils is activated to a greater extent in crop rotation, by monoculture and background of organic system of fertilizers. Therewith, mineral systems of fertilizers don't inhibit activity of hydrolytic and redox enzymes under recommended norms.

Increment of hydrolytic activity of soils has a direct impact on level of yield capacity of oilseed flax. Thereupon, indices of hydrolytic activity of soils can be used as a test for diagnosis of efficiency of fertilizers systems both within crop rotation and by monoculture.

Introduction

In order to provide rich and high quality harvest of different crops, the most important condition is a development of implementation use of complex agrotechnical techniques, fertilizers application systems, including usage of optimal doses of mineral and organic fertilizers [1-2].

It has been found that soil enzymes while participating in the most important biological cycles of carbon, nitrogen, phosphorus, sulphur and other organogenic elements, determine a way of soil formation, level of fertility of the soil and, thus, directly impact yield capacity of crops [3-5].

The application of large doses of fertilizers, especially during the watering, may in some cases have a negative impact on biological activity of soils, particularly, over enzymatic activity thereof and, thus, adversely affect productivity of crops [6-7].

The research on this problem concerning soils of our country is quite limited, whereas published data on soils of other countries can not be compared or used in connection with soils of Kazakhstan [8-10].

Considering the above mentioned research of different fertilizers systems impact over soils yield capacity and fertility within crop rotation and by monoculture as related to the direction of change of biological activity indices is an urgent problem for soil-science and agricultural chemistry being of interest not only for Kazakhstan but also abroad [11-13].

Materials and methods

Stationary experiments of the department "Soil Science, agricultural chemistry and ecology" of Kazakh National Agrarian University, which were first initiated by R.E. Eleshev in 2001 have been the objects of the current research. The tests were devoted to four-field crop rotation and monoculture in order to investigate impact of organic, organic and mineral and mineral fertilizers systems on biological activity of soils and productivity of oil-bearing crops.

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Four-field crop rotation can be presented in time and space in the following cycle of cultures: 1 – barley; 2 – flax; 3 – mustard; 4 – castor-oil plant.

Fertilizers for oil-bearing crops in conformity with crop rotation and by monoculture of oilseed flax were studied according to the following variants: 1 – Control (without fertilization); 2 – Estimated dose $N_{75}P_{70}K_{45}$; 3 – Manure, 30 t/ha; 4 – ½ Manure + ½ NPK; 5 – Biohumus, 3 t/ha; 6 – Straw, 5 t/ha.

Soil of experimental ground was piedmont-chestnut. Eight (8) cutaway sections were located on typical chestnut soils, their morphological characteristics were described resulting in choice of sample soils by genetic horizons. In addition, individual samples for statistical data processing were taken out of heeling. In course of stationary experiments soil samples from depth 0-20, 20-40 cm. at the end of crop rotation and by monoculture have been subject matter of analysis.

Agrochemical indices of soils were determined via application of common methods (Agrochemical research of soils, 1975). Content of humus in plough-layer constitutes 4.38% and decreases gradually with the depth up to 1.66%, pH – 7.7-8.0, total absorbed bases – 13.6 meq. per 100 g., CO_2 (carbonates) – 5.8%. Content of total nitrogen, phosphorus and potassium is 0.258, 0.211 and 2.85%, respectively. Provision with easily hydrolysable nitrogen is medium, with fluent phosphorus- low and with potassium is medium-high.

We have also studied the activity of two (2) groups of enzymes: hydrolytic (invertase, ATPase, phosphatase) and redox enzymes (catalase, dehydrogenase). Determination of enzymes activity and intensity of soil "breathing" were carried out via Galstyan's methods [14].

In order to establish connection between biological activity and yield capacity, long term annual average experimental data on flax within crop rotation and by monoculture were used.

Harvest record in experiments was carried out manually, taking into consideration each allotment and fourfold replication.

Mathematical data processing of yield capacity by crop rotation, monoculture and correlated regression analysis of enzymes were conducted via methods of Fisher, J. Tukey, etc.

Results and discussion

Analysis of natural biological condition of chestnut soil under research by genetic horizons has showed that they have moderate activity of hydrolytic (invertase, urease, ATPase, phosphatase), redox (catalase, dehydrogenase) enzymes and the intensity of the "breathing" (Table 1).

Table 1
The enzymatic activity of the irrigated chestnut soils by genetic horizons (input data)

Horizon	A arable	B1	B2	BC
Layer of soil, sm.	0-25	25-46	46-58	58-76
Humus, %	4.38	4.47	3.05	1.66
CO_2,%	5.80	5.84	5.88	7.30
Total nitrogen, %	0.258	0.248	0.214	0.117
Fractions<0,001, mm.	19.65	20.19	15.43	26.23
Fractions<0,01, mm.	46.71	46.95	49.38	55.27
pH H_2O	8.0	8.1	8.2	8.3
Invertase, mg. Glucose per 1 g.	18.9	9.6	3.3	2.0
Phosphatase, mg P per 100g.	4.23	2,36	1.6	1.22
Ureasa, mg. NH_3 per 1 g.	2.87	2.55	1.27	0
ATPase, mg. P per 100 g.	4.53	1.25	0.26	0.13
Dehydrogenase, mg. TFF per 10 g.	5.4	2.6	0.4	0
Catalase cm^3 O_3 per 1 g.	9.7	8.7	6.2	5.0

The last one apparently relates to the peculiarity of natural climate conditions of soil formation and relatively low level of potential fertility of soils under research because of energetic decay of organic matter due to low humidity and high temperature.

The contents of all groups of enzymes (in particular, hydrolases) are dependent to a greater extent from the content of humus.

Thus, the invertase activity in the upper humus horizon is 18.9 mg. of glucose per 1 g. of soil, with a correlation coefficient of 80.2%, if the amount of invertase is changed by 1, the percentage of humus will be increased by 0.136.

The interrelation between invertase and the content of humus is expressed by the following regression equation:

$$Y = 2.241 + 0{,}136x \quad (1)$$

Determination coefficient is 64.3%, i.e. change of the content of humus to 64.3% is related to invertase activity.

Phosphatase activity of chestnut soils - 4.23 mg. P per 100 g. of soil. The correlation coefficient is 76.8%, which also shows the close interrelation with the content of humus and is expressed by the following regression equation:

$$Y = 1.165 + 0{,}760x \quad (2)$$

Urease activity in the humus-accumulative horizon is 2.87 mg. NH_3 per 1 g. of soil, its activity is completely suppressed deeper than 40 cm. of layer due to low biogenity and low supply of nitrogen to soils.

The close interrelation between urease and the content of humus is expressed by the following regression equation (3), with correlation coefficient 99.1% and determination coefficient 98.2%:

$$Y = 1.51 + 1{,}000x \quad (3)$$

The dependence of the ATPase on the humus is expressed by the following regression equation (4), with correlation coefficient 67.7% and determination coefficient 45.8%:

$$Y = 2.405 + 0{,}436x \quad (4)$$

Dehydrogenases being an aggregate indicator of microbial activity in soil and in soil under research are less active. Their activity is also closely related to the content of humus and is expressed by the following regression equation (5) with correlation coefficient 81.5% and determination coefficient 66.4%:

$$Y = 2.031 + 0.435x \quad (5)$$

We have analyzed the dependence of the catalase on content of humus, with correlation coefficient 95.5% and determination coefficient 91.2%, and such dependence is expressed by the following regression equation (6):

$$Y = -1.26 + 0.581x \quad (6)$$

The level of enzyme activity and inactivation of soil enzymes also depend on the mechanical structure. That is more obvious when comparing the distribution data of silty and fine dust fractions by genetic horizons and biological activity (invertase, urease, ATPase, phosphatase).

Observed regularities correlate with data of the following researchers: Vasilenko Ye.S. (1962), Geltser Ju.G. (1990), Tazabekova Ye.T. (1998), while differ in relative and absolute values of certain enzymes groups (Eleshev R.E., 2010).

The results of research conducted under conditions of lasting stationary experiment have shown that fertilizers and crop rotation have a positive impact primarily on the activity of hydrolytic enzymes, without significant effect on change in the contents of groups of redox enzymes.

It was found that biological activity of hydrolytic enzymes (invertase, urease, ATPase, phosphatase) in fertilized flax by monoculture was 20-30% lower compared to the same in flax within the crop rotation (Tables 2-3).

The last apparently relates to improved water, air, soil nutrient regimes, as well as soils enrichment with organic and organic and mineral compounds in course of change of cycles within crop rotation.

Different levels of hydrolytic activity of soils, which are created within the background of fertilizers systems in crop rotation and by monoculture, had different impacts on the level of yield capacity of oilseed flax. In turn, the degree of positive effect of crop rotation becomes even more apparent through the use of fertilizers.

Effects of fertilizers on biological activity of soils within crop rotation and by monoculture are not identical (Tables 2-3).

Within crop rotation (Table 2) a higher level of activity of hydrolytic enzymes is observed on the variants with the estimated quantities of fertilizers and joint application of manure and mineral fertilizers in the half-norms.

In the territory of flax monoculture (Table 3) variants with organic fertilizers (particularly, manure and biohumus) were more efficient in terms of increasing activity of hydrolytic enzymes.

Table 2

Biological activity of chestnut soil under sowing of oilseed flax in crop rotation within the background of the various fertilizers systems

№	Variant	Layer of soil. sm.	Activity					Yield capacity of oilseed flax, c/ha
			Invertase, mg. glucose	Urease, mg. NH_3 per 1 g.	ATPase, mg. P per 100g.	Dehydrogenase, mg. TFF per 10g. of soil	Catalase cm^3 O_3 per 1g. per 1 min.	
1	Control	0-20	18.2	3.3	2.2	2.0	13.6	15.9
		20-40	12.4	2.38	0.7	1.5	14.6	
2	Estimated dose $N_{75}P_{70}K_{45}$	0-20	22.8	5.25	3.8	2.45	7.85	21.9
		20-40	18	4.5	1.2	1.85	9.4	
3	Manure, 30 t/ha	0-20	21.2	6.45	5.06	3.1	11.1	20.2
		20-40	19.1	5.3	3.1	1.9	11.9	
4	½ manure + ½ NPK	0-20	24.8	4.57	5.2	2.8	11.6	21.2
		20-40	18.6	3.9	1.6	1.3	19.1	
5	Biohumus, 3 t/ha	0-20	18.1	6.54	3.5	2.4	18.3	19.4
		20-40	15.8	4.76	1.4	1.6	11.3	
6	Straw, 5 t/ha	0-20	17.9	5.6	3.4	2.0	5.9	17.6
		20-40	14	3.8	5.6	1.35	9.1	
Absolute value LSD $_{0,05}$								2.44
Relative value LSD $_{0,05}$								1.96

Table 3

Biological activity of chestnut soil by monoculture of oilseed flax within the background of the various fertilizers systems (by the end of the 2-nd rotation)

№	Variant	Layer of soil, Sm.	Activity					Breathing CO_2 per 100g. of soil	Yield capacity of oilseed flax c/ha
			Invertase, mg. glucose	Urease, mg. NH_3 per 1g.	ATPase, mg. P per 100g.	Dehydrogenase, mg. TFF per 10g. of soil	Catalase cm^3 O_3 per 1g. per 1 min.		
1	Control	0-20	14.25	4.08	1.59	1.25	11.7	24.5	12.4
		20-40	6.7	2.8	0.88	0.88	17.4	22	
2	Estimated dose $N_{75}P_{70}K_{45}$	0-20	16.5	5.03	7.1	15.45	26.5	21.7	14.5
		20-40	13	4.1	4.3	1.25	16.4	20.4	
3	Manure, 30 t/ha	0-20	19.5	4.4	7.32	2.4	11.2	36.4	16.9
		20-40	9.5	3.5	3.4	1.7	14.2	26.4	
4	½ manure + ½ NPK	0-20	17	4.4	7.37	2.1	14.8	24.9	14.9
		20-40	14	3.8	5.6	1.35	18.1	18.1	
5	Biohumus, 3 t/ha	0-20	19	5.1	7.15	2.4	14.3	28.6	16.1
		20-40	14.5	4.27	3.6	1.2	13.2	24.1	
6	Straw, 5 t/ha	0-20	14.5	4.25	3.2	1.6	13.5	24.3	13.5
		20-40	5.6	3.5	1.5	1.2	15.4	17.6	
Absolute value LSD $_{0,05}$									2.25
Relative value LSD $_{0,05}$									2.29

Within crop rotation, higher harvest of flax is formed within the background of mineral (21.9 c/ha) and organic and mineral systems (21.2 c/ha). In monoculture of flax, the highest harvest is ensured via manure (16.9 t/ha) and biohumus (16.1 c/ha), i.e. within the organic system.

The observed interrelation between yield capacity of flax and the level of hydrolytic activity of soils allows using hydrolase enzymes as a diagnostic test of efficiency of fertilizers systems in irrigated agriculture.

Conclusions

1. Piedmont chestnut soils of Zailiyskiy Alatau are characterized by moderate activity of hydrolytic (invertase, urease, ATPase, phosphatase) and redox enzymes (catalase, dehydrogenase).

Crop rotation and fertilizers increase activity of hydrolase enzymes by 20-30% without significant impact on the activation of groups of redox enzymes.

2. The level of activation of hydrolytic enzymes depends on the fertilizers systems. Within crop rotation the higher level of hydrolytic enzymes is ensured within the background of mineral and organic systems, whereas in monoculture the same result is ensured on variants with organic fertilizers (manure, biohumus).
3. We have found the dependence of the harvest flax formation on the level of hydrolase enzymes. The highest harvest of flax in the crop rotation fields was ensured by background $N_{75}R_{70}K_{45}$ (21.9 c/ha) and ½ manure + ½ NPK manure (21.2 c/ha). In sowing of monoculture of flax the higher harvest is formed within the background of manure (16.9 c/ha) and biohumus (16.1 c/ha), i.e. via organic systems.

References

1. Eleshev R.E., Bakenova Zh.B. and others. The adaptive technology of cultivation of oilseeds (flax, mustard, castor-oil plant) on the irrigated lands of the south-east of Kazakhstan // Recommendation, Almaty, 2011, p.25.
2. Eleshev R.E., Ivanov A.L., Perevertin K.A. Optimization of doses of fertilizers in crop rotations // Bulletin of agricultural science of Kazakhstan, 1990, №4, p.27-29.
3. Goncharova L.Ju., Bezuglova O.S., Valkov V.F. Season dynamics of content of humus and enzymatic activity of black soil (carbonate) // Eurasian Soil Science, 1990, № 10. p. 86-93.
4. Khaziev F.Kh. Soil enzymes. M.: Publ. h. Science, 1972, p. 48
5. Sherbakov A.P., Nanstein V.N. Soil fertility and nutrients balance in agriculture of Central Chernozem Region // Increase of soil fertility and productivity of crops by intensive chemization. M.: Publ. h. Science, 1983. p. 153-169.
6. Braunstein A.Ye. Modern conceptions on mechanism of catalytic effect of enzymes. M.: Publ. h. Science, 1982, p. 239
7. Burdukov V.G., Telukin V.A. The biological activity of soils under different conditions of plant nutrition and irrigation // Agricultural chemistry. 1983. №4. p. 90-94.
8. Parinkina O.M., Kluyeva N.V., Petrova L.G. The biological activity and effective soil fertility // Eurasian Soil Science, №9, 1996, p. 76-81.
9. Tazabekov T.T., Tazabekova T.T. Effects of cultivation on biological activity of soils of Zailiyskiy Alatau // Eurasian Soil Science, 1985, № 5, p. 65-67.
10. Khaziev F.Kh., Khabirov I.K. Physical and geographic factors and enzymatic activity of soils // Eurasian Soil Science, 1983, №11, p. 57-65.
11. Tazabekova Ye.T. The enzymatic activity of soils of Kazakhstan and ways of regulation thereof. Almaty, 1998. p. 159-167.
12. Balota, Ye.L., Colozzi-Filho, A.; Andrade, D.S.; Dick, R.P. Microbial biomassin soils under different tillage and crop rotation systems. Biol. Fertil. Soils., 38:15-20, 2003.
13. Tazabekov T.T., Rubinstein M.J., Tazabekova Ye.T. The biological activity of Zailiyskiy Alatau soils // Eurasian Soil Science, 1986, p.45

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