

**EFFECT AND EVALUATION OF ZEOLITE AND BIOHUM ON BIOLOGICAL INDICATORS OF IRRIGATED SEED-GRAY SOILS**

**ABSTRACT**

The effect of zeolite and biohumus on the biological activity of irrigated grass-gray soils under beans of the subtropical zone was studied. It was determined that the biological activity of the irrigated grass-gray soils changes depending on the growth phase of the bean, the applied biohumus and zeolite rate. Based on complex biological indicators (activity of enzymes, the number of microorganisms, abundance of carbon dioxide released from the soil, intensity of the nitrification process, intensity of decomposition of cellulose), bio-diagnostics of irrigated meadow-gray soils were given, an integral indicator of the biological condition of the soil was determined, and a biological assessment was carried out.

**The purpose** of the work is to determine the effect of biohumus and zeolite on the biological activity of irrigated grass-gray soils used under the bean plant, and to conduct a biological evaluation based on complex biological indicators.

**The research object** is irrigated meadow-gray soils (in WRB - IrragicCalsisols) of the subtropical zone, various doses of biohumus and zeolite, small bean-mung bean (*VignaAngularis*) plant. Scheme of the experiment: 1. control (without fertilizer); 2. biohumus 5 t/ha; 3. zeolite 5 t/ha (clinoptilolite); 4. biohumus 5 t/ha + zeolite 5 t/ha; 5. biohumus 7.5 t/ha; 6. zeolite 7.5 t/ha; 4. biohumus 7.5 t/ha + zeolite 7.5 t/ha.

Mathematical-statistical calculation of the numbers obtained as a result of the research was carried out based on the Anova package in Excel. The obtained results show a significant difference between the variants and compared to the control.

**Keywords:** Irrigated meadow-gray soils; biological activity; small vegetable bean plant; biohumus and zeolite; biological assessment.

**1.INTRODUCTION**

In order to maintain the level of soil fertility and predict it, it is necessary to study the soil comprehensively, including the microbial population and biological activity, so it is very important to study the biological state of the soil and its changes due to various external influences [6]. Recently, indicators of biological activity are used as bioindicators in determining long-term agrotechnological impact [10]. Microbiological (number, composition of various groups of micro- and meso-organisms, biomass of microorganisms, etc.) and biochemical (level of enzyme activity, nitrification ability, cellulose decomposition intensity, soil

respiration, etc.) indicators are used in the complex assessment of soil biological activity and fertility. [1; 8].

The complex study of soil biological activity, physical, chemical, microbiological, and biochemical properties allows us to clarify their ecological-genetic characteristics, as well as the influence degree of natural and ecological factors on soil fertility [18].

Indicators of biological activity are more informative in soil condition monitoring and bio-diagnostics, the number of microorganisms related to nitrogen cycle and enzymatic activity are the main indicators in soil condition assessment [3], so the authors suggest evaluating soils according to enzyme activity and microbial biomass [26].

The purpose of the work is to determine the effect of biohumus and zeolite on the biological activity of irrigated meadow-gray soils used under the bean plant, and to conduct a biological evaluation based on complex biological indicators.

## 2. MATERIALS AND METHODS

### 2.1. Research object

The object of the research is irrigated meadow-gray soils (in WRB - IrragicCalsisols). The hydrological conditions of the territory, especially the mode and level of groundwater, the duration and intensity of artificial irrigation play a significant role in the genesis of meadow-gray soils. Signs of salinization and siltation are often found in the morphological structure of meadow-gray earth-irrigated soils. The arable horizon contains 1.3-2.8% of humus with a natural increase from newly irrigated low-culture to oasis-irrigated high-culture. In poorly cultivated varieties, the content of exchangeable Na increases from a depth of 30-40 cm, which, against the background of increased alkalinity, contributes to the saltiness of these soils.

### 2.2. Methods

Experiments were carried out with small bean-mung bean plant (*VignaAngularis*) in 7 variants and each variant in 3 replicates. The scheme of the experiment is as follows: 1. control (without fertilizer); 2. biohumus 5 t/ha; 3. zeolite 5 t/ha (clinoptilolite); 4. biohumus 5 t/ha + zeolite 5 t/ha; 5. biohumus 7.5 t/ha; 6. zeolite 7.5 t/ha; 4. biohumus 7.5 t/ha + zeolite 7.5 t/ha.

The activity of invertase, phosphatase and catalase enzymes was determined according to FX Khaziyev [12], the amount of microorganisms of the Moscow Institute of Microbiology, the amount of carbon dioxide released from the soil according to VI Titova [11], the intensity of the nitrification process and the intensity of cellulose decomposition according to the method of IS Vostrov [2]. The mathematical-statistical report of the actual numbers obtained as a result of the research was made based on the Anova package in Excel.

## 3. RESULTS and DISCUSSION

### 3.1. Biodiagnostics of meadow-gray soils irrigated under bean plants

#### 3.1.1. Invertase enzyme activity

Soil enzymes play an important role in the cycle of basic nutrients, energy flow, and formation of physical and chemical properties of soils [24]. Thus, information on the activity of enzymes can be used to determine changes in soil properties due to environmental changes and to control processes in the soil ecosystem [15].

Actual numbers obtained for biological indicators in irrigated meadow-gray soils under bean plants were mathematically and statistically processed, and bio-diagnostics were given based on them.

As can be seen from the obtained figures, the activity of the invertase enzyme varied from 7.46 to 9.78 mg of glucose in 10 g of soil in 24 hours, depending on the variants. This indicator in the 0-25 cm layer is 7.46 in the control variant, 8.86 in the biohumus 5 t/ha variant, 7.65 in the zeolite 5 t/ha variant, 9.52 in the biohumus 5 t/ha + zeolite 5 t/ha variant, 9.46 in the biohumus 7.5 t/ha variant, zeolite Glucose was 7.64 in the 7.5 t/ha option and 9.78 mg in the biohumus 7.5 t/ha + zeolite 7.5 t/ha option (table).

From the obtained figures, it can be seen that the activity of invertase enzyme was relatively high in the variants where biohumus was given alone and together with zeolite, but it was not significantly different from the control in the variants where zeolite was given alone.

#### 3.1.2. Phosphatase enzyme activity

Soil enzymes are among the most active organic components of the soil, they participate in all biochemical processes occurring there, therefore their activity is more sensitive than physical and chemical indicators and can accurately reflect the conditions of soil regeneration in different ecosystems [25]. In addition, many researchers show that human economic activities, such as land use and fertilization, significantly affect the activity of soil enzymes [25]. The activity of urease, alkaline phosphatase and catalase enzymes is more sensitive to environmental changes [17].

In irrigated grass-gray soils, the activity of phosphatase enzyme under the bean plant in the 0-25 cm layer was 1.55 in the control variant, 1.80 in the biohumus 5 t/ha variant, 2.25 in the zeolite 5 t/ha variant, 2.75 in the biohumus 5 t/ha + zeolite 5 t/ha variant, 1.95 in biohumus 7.5 t/ha variant, 2.31 in zeolite 7.5 t/ha variant and 2.95 in biohumus 7.5 t/ha + zeolite 7.5 t/ha variant, 1.37 in 25-50 cm layer respectively; 1.61; 1.97; 2.43; 1.70; 1.96 and 2.60 mg of P<sub>2</sub>O<sub>5</sub>. In all variants, the activity of phosphatase enzyme increased with the increase in fertilizer rates. The activity in the options where zeolite was applied was higher than in the options where biohumus was applied alone, and the activity fluctuated between 1.37-2.60 mg P<sub>2</sub>O<sub>5</sub> for all options. From this, it can be seen that nutrients are absorbed by zeolite during the growing season of the bean plant and released into the environment when the plant needs to use them.

### 3.1.3. Catalase enzyme activity

Depending on the complexity of soil organic matter (SOM), microorganisms produce different hydrolases and oxidoreductases [14]. The activity of urease, alkaline phosphatase and catalase enzymes is more sensitive to environmental changes [17].

In irrigated meadow-gray soils, an increase in the activity of catalase enzyme was observed under the bean plant, depending on the variants, relative to the control, and the activity in the 0-25 cm layer fluctuated between 5.7-7.8 cm<sup>3</sup> O<sub>2</sub>. In irrigated meadow-gray soils, the activity of catalase enzyme in the 0-25 cm layer was 5.7 in the control variant, 6.9 in the biohumus 5 t/ha variant, 5.9 in the zeolite 5 t/ha variant, 7.1 in the biohumus 5 t/ha + zeolite 5 t/ha variant, biohumus 7.5 t 7.6 in the /ha variant, 6 in the zeolite 7.5 t/ha variant and 7.8 cm<sup>3</sup> O<sub>2</sub> in the biohumus 7.5 t/ha + zeolite 7.5 t/ha variant.

The activity of catalase enzyme was significantly lower in the sub-crop layer than in the crop layer. In the variants where zeolite was applied, the activity was less compared to the variants where biohumus was applied alone.

### 3.1.4. Amount of microorganisms

Soil microorganisms and enzymes are actively involved in the decomposition of organic matter and humus, providing plants with nutrients [9; 23]. Some authors show that there is evidence that the loss of the microorganisms diversity can lead to the decline of many functions of the ecosystem [19].

Microorganisms form part of soil biomass and contribute to soil nutrient enrichment, which is mainly called microbial biomass [23].

The amount of microorganisms in the control layer is 1854, biohumus 5 t/ha variant 2063, zeolite 5 t/ha variant 1975, biohumus 5 t/ha + zeolite 5 t/ha variant 2289, biohumus 7.5 t/ha variant 2373, zeolite 7.5 t/ha 2297 in the option and 2467 in the option of biohumus 7.5 t/ha + zeolite 7.5 t/ha, 1387 in the subsoil layer accordingly; 1542; 1489; 1768; 1821; 1759 and 1983 thousand/units were formed in dry land. From the obtained figures, it can be seen that the increase compared to the control is 182 thousand (10.1%) in the option of biohumus 5 t/ha, 111 (6.4%) in the option of zeolite 5 t/ha, 408 (20.1%) in the option of biohumus 5 t/ha + zeolite 5 t/ha , 476 thousand (22.8%) in biohumus 7.5 t/ha variant, 407 thousand (20.1%) in zeolite 7.5 t/ha variant and 604 thousand (27.1%) in biohumus 7.5 t/ha + zeolite 7.5 t/ha variant. In comparison, the largest amount of microorganisms was recorded in the options where biohumus was applied. As a result of the application of zeolite, there was a significant increase in the amount of microorganisms compared to the control. It seems that the reason for this is unfavorable soil conditions, zeolite retains water and regulates plant development.

### 3.1.5. Decomposition intensity of cellulose

Cellulose degradation intensity should be the first step in assessing the physical and chemical properties and suitability of irrigated soils before various agricultural operations [27].

There was no significant difference between the variants in terms of cellulose degradation intensity. So, this indicator varied between 23.3-30% depending on the options, in comparison, the highest indicator was recorded in the biohumus 7.5 t/ha + zeolite 7.5 t/ha variant. The intensity is 23.3 in the control variant, 25.4 in the biohumus 5 t/ha variant, 26.7 in the zeolite 5 t/ha variant, 28.7 in the biohumus 5 t/ha + zeolite 5 t/ha variant, 27.5 in the biohumus 7.5 t/ha variant, 29.1 in the zeolite 7.5 t/ha variant and biohumus 7.5 t/ha + zeolite 7.5 t/ha made 30%. The increase in cellulose decomposition intensity was higher in the variants where zeolite was applied alone and together with biohumus compared to the variants where biohumus was applied alone, which is related to the adsorption capacity of zeolite. 15% increase compared to control in biohumus 5 t/ha variant, 8% in zeolite 5 t/ha variant, 27% in biohumus 5 t/ha + zeolite 5 t/ha variant, 23% in biohumus 7.5 t/ha variant, zeolite 7.5 t/ha 22% in the option and 33% in the option of biohumus 7.5 t/ha + zeolite 7.5 t/ha. From the obtained figures, in the biohumus 7.5 t/ha option, the increase is 8% compared to the biohumus 5 t/ha option, in the zeolite 7.5 t/ha option, 4% compared to the zeolite 5 t/ha option, in the biohumus 7.5 t/ha + zeolite 7.5 t/ha was 6% more than the variant biohumus 5 t/ha + zeolite 5 t/ha (table).

### **3.1.6. Intensity of sequestration of carbon dioxide from the soil**

When the plants die or are harvested, the leaves, stems and roots of the plant left in the soil rot, and the carbon is then converted into soil organic carbon (SOC) [20].

In the irrigated meadow-gray soils, the intensity of carbon dioxide release from the soil in the 0-25 cm layer varied between 2.4-5.7 mg CO<sub>2</sub>/10 g of soil/24 hours, depending on the options. The intensity of carbon dioxide release from the soil is 2.4 in the control variant, 4.4 in the biohumus 5 t/ha variant, 3.2 in the zeolite 5 t/ha variant, 5.3 in the biohumus 5 t/ha + zeolite 5 t/ha variant, 4.9 in the biohumus 7.5 t/ha variant, zeolite 7.5 t/ha option 3.4 and biohumus 7.5 t/ha + zeolite 7.5 t/ha option was 5.7 mg CO<sub>2</sub>/10 g soil/24 hours. Variants in which biohumus was applied significantly affected the intensity of carbon dioxide release from the soil and the increase was 2.0-2.5 times higher. The reason for this seems to be the rapid development of plants and root systems, the rapid growth of microorganisms and the respiration of the living system in the soil during the application of biohumus.

In the studied soils, a decrease in the intensity of soil "respiration" was observed along the profile, which indicates that the intensity of soil "respiration" depends on the speed of the soil compaction processes and the properties of the soil [18].

Variants in which biohumus was applied alone and together with zeolite had a significant effect on the intensity of carbon dioxide release from the soil, but in the variants in which zeolite was applied alone, the intensity did not differ significantly compared to the control.

### 3.1.7. Intensity of the nitrification process

The intensity of the nitrification process fluctuated between 10.3-14.6 mg/kg N-NO<sub>3</sub> depending on the options in irrigated meadow-gray soils. In irrigated meadow-gray soils, the intensity was 10.8 in control, 12.6 in biohumus 5 t/ha variant, 10.3 in zeolite 5 t/ha variant, 13.7 in biohumus 5 t/ha + 5 t/ha variant, biohumus 7.5 t/ha variant 14.2, zeolite 7.5 t /ha was 10.7 and biohumus 7.5 t/ha + zeolite 7.5 t/ha was 14.6 mg/kg NO<sub>3</sub>.

The reason for the decrease in the intensity of the nitrification process when mixing zeolite with soil seems to be that NH<sub>4</sub><sup>+</sup> is adsorbed by the zeolite mineral cage, which prevents leaching of mineral nitrogen [16; 22]. Efficient use of nitrogen is important in crop cultivation. In modern agricultural science, biological fertilizers slow down the nitrification process and increase soil fertility [21; 22].

The intensity of the nitrification process was not significantly different in the variants where zeolite was applied compared to the control, but it was higher in the variants where biohumus was given alone and in complex with zeolite.

### 3.2. Integral indicator of the biological status of irrigated meadow-gray soils under the bean plant (IIBSS) and biological evaluation

In order to combine multiple biological indicators of soils, a method of using the integral indicator of the ecological and biological condition of the soil (IIBSS) was developed. This method allows to evaluate the sum of biological indicators. For this, the maximum value of each indicator in the soil sample is evaluated as 100%, and the value of the same indicator is expressed as a percentage in the remaining samples.  $B1 = (Bx / Bmax) \times 100\%$ , (1) where B1 - the relative score of the indicator, Bx - the actual value of the indicator, Bmax - the maximum value of the indicator [4]. According to the most informative indicators of the biological condition of the soil, it is recommended to determine the integral indicator of the ecological and biological condition of the soil, the decrease of the integral indicator of the ecological and biological condition of the soil directly depends on the degree of influence of anthropogenic factors [5].

Table 1. Biodiagnostics of irrigated grass-gray soils

Variants	Depth, cm	Invertaze, mq glucose	Phos-phatase, mg P <sub>2</sub> O <sub>5</sub>	Catalaze, cm <sup>3</sup> O <sub>2</sub>	Decompos. intensity of cellulose, %	mg CO <sub>2</sub> /10 g soil/24 hours	Nitrifi-cation, mg N-NO <sub>3</sub>	Amount of microorga-nisms, thous./g
Control	0-25	7,46	1,55	5,7	23,3	2,4	10,8	1854
	25-50	5,53	1,37	4,5		1,8	9,1	1387
	0-50	6,50	1,46	5,1		2,2	9,9	1621
Biohumus 5 t/hect	0-25	8,86	1,80	6,9	25,4	4,4	12,6	2063
	25-50	7,21	1,61	5,7		3,0	10,4	1542
	0-50	8,01	1,71	6,3		3,7	11,5	1803
Zeolit 5 t/hect	0-25	7,65	2,25	5,9	26,7	3,2	10,3	1975
	25-50	6,08	1,97	4,9		2,1	9,1	1489
	0-50	6,87	2,11	5,4		2,7	9,7	1732
Biohumus 5 t/hect + zeolit 5 t/hect	0-25	9,52	2,75	7,1	28,7	5,3	13,7	2289
	25-50	7,95	2,43	6,4		3,6	10,9	1768
	0-50	8,74	2,59	6,8		4,4	12,4	2029
Biohumus 7.5 t/hect	0-25	9,46	1,95	7,9	27,5	4,9	14,6	2373
	25-50	7,90	1,70	7,1		3,6	12,3	1821
	0-50	8,67	1,82	7,5		4,3	13,5	2097
Zeolit 7.5 t/hect	0-25	7,64	2,31	6,0	29,1	3,4	10,7	2297
	25-50	6,08	1,96	5,3		2,3	9,5	1759
	0-50	6,86	2,14	5,7		2,9	10,1	2028
Biohumus 7.5 t/hect + zeolit 7.5 t/hect	0-25	9,78	2,95	7,8	30,0	5,7	14,6	2467
	25-50	8,68	2,60	7,1		4,0	12,0	1983
	0-50	9,24	2,78	7,5		4,9	12,9	2225

Assessment of the biological condition of soils is determined by the activity of hydrolytic and oxidation-reduction enzymes involved in humification and mineralization processes, because their activity is the main criterion of soil fertility [13]. Enzymatic activity of soils is an important diagnostic indicator that is often used to assess the condition of various agricultural soils [7]. Biomonitoring, biodiagnostics and bioindication of soils are of greater importance in terms of carrying out scientific research and implementation of experimental measures [4].

In the irrigated meadow-gray soils of the research object, IIBS was determined both according to the options and the crop and sub-crop layers, and a biological evaluation of the soils was carried out according to biological indicators. The activity of invertase, phosphatase and catalase enzymes, the intensity of cellulose decomposition and the release of carbon dioxide from the soil, the nitrification ability of the soil and the amount of microorganisms were used in the calculation of IIBSS.

In the irrigated meadow-gray soils of the research object, IIBSS varied between 76-100% due to the activity of the invertase enzyme under the bean plant. This indicator is 76 in control, 91 in biohumus 5 t/ha variant, 78 in zeolite 5 t/ha variant, 97 in biohumus 5 t/ha + zeolite 5 t/ha variant, 97 in biohumus 7.5 t/ha variant, 78 in zeolite 7.5 t/ha variant. and biohumus 7.5 t/ha + zeolite 7.5 t/ha was 100%.

It is clear from this that in the options where biohumus is given alone and together with zeolite, IIBSS is higher than the control due to the activity of the invertase enzyme, and in the options where zeolite is given alone, this indicator did not differ significantly compared to the control. IIBSS fluctuated between 53-100% due to phosphatase enzyme activity in irrigated meadow-gray soils. In all options, the activity of phosphatase enzyme increased with the increase of fertilizer rates, and the increase varied from 8-47% depending on the options compared to the control.

According to the activity of catalase enzyme, depending on IIBSS variants, the increase compared to the control fluctuated between 15-87%. In the variants where zeolite was applied, the increase compared to the control was between 3-4 units.

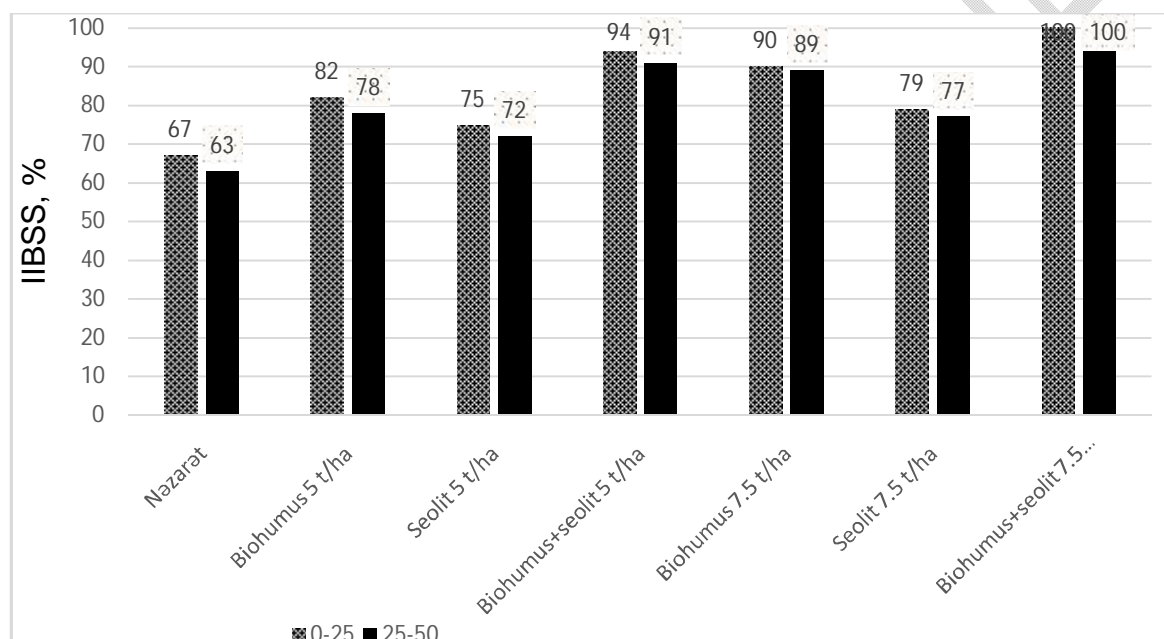
According to the amount of microorganisms, IIBSS varied between 75-100 units depending on the options, in comparison, the highest indicator was recorded in the options where biohumus was applied.

The calculation of IIBSS according to the intensity of cellulose decomposition shows that there was no sharp difference between the variants. Thus, this indicator changed in the range of 78-100%, the highest indicator (100%) was recorded in the option of biohumus 7.5 t/ha + zeolite 7.5 t/ha. According to the intensity of cellulose decomposition, the growth of IIBSS biohumus and zeolite either alone or in a complex application of both was higher than the control. This is related to the adsorption capacity of zeolite.

Depending on the variants, IIBSS varied between 42-100% depending on the carbon dioxide abundance in irrigated meadow-gray soils. Options for applying biohumus significantly affected the intensity of carbon dioxide released from the soil, and this indicator fluctuated between 42-100% depending on the options.

Due to the intensity of the nitrification process, IIBSS changed between 74-100 units. This indicator was weaker in the variants where zeolite was applied. This is due to the adsorption of nutrients in the soil by zeolite and their gradual assimilation by plants.

The calculation of IIBSS according to the obtained biological indicators shows that the biological assessment of the irrigated meadow-gray soils under beans was between 67-100%. In the biological evaluation, TBVIG was 67% in the control variant, 82% in the biohumus 5 t/ha variant, 75% in the zeolite 5 t/ha variant, 94% in the biohumus 5 t/ha + zeolite 5 t/ha variant, 90% in the biohumus 7.5 t/ha variant, 79% in the zeolite 7.5 t/ha variant and 100% in the biohumus 7.5 t/ha + zeolite 7.5 t/ha variant (picture).



**Fig 1: Integral indicator of the biological condition of irrigated meadow-gray soils (0-25 and 25-50 cm layers)**

Thus, in the options where biohumus and zeolite are applied at the rate of 7.5 t/ha in the irrigated grass-gray soils, the increase in IIBSS compared to the control was less compared to the options where biohumus and zeolite were applied at the rate of 5 t/ha.

## CONCLUSIONS

The application of zeolite and biohumus in the irrigated meadow-gray soils of the subtropical zone led to changes in biological indicators in different directions.

The complex application of biohumus with zeolite significantly affected the activity of biological indicators.

Based on complex biological indicators, biodiagnosis of irrigated meadow-gray soils is given.

Based on the complex biological indicators, the integral indicator of the biological condition of the irrigated grass-gray soils was high according to the evaluation scale in the option of complex application of biohumus with zeolite.

## REFERENCES

1. Ashirbekov MZh. Influence of cotton crop rotations on microbiological and biochemical properties of old-irrigated serozhomo-meadow soils of southern Kazakhstan. Bulletin of the Altai State Agrarian University. 2015; 7(129): с. 64-69.
2. Vostrov I.S., Petrova A.N. Determination of biological activity of soil by different methods // Microbiology, 1961, T. 30, No. 4, p. 665-672
3. Zabelina O.N. Assessment of the ecological condition of the soil of urban recreation areas based on indicators of biological activity (on the example of the city of Vladimir) 03.02.08 – ecology (biology) Dissertation for the degree of candidate of biological sciences Vladimir 2014, 148 с.
4. Kazeev K.Sh., Kolesnikov S.I., Valkov V.F. Biology soil of Russia. Rostov-na-Donu: Изд-во ЦББП, 2004, 350 с
5. Kazeev K.A. The experience of applying enzymatic activity in the evaluation of the ecological state of soils of natural and disturbed territories / Biodiagnostics and evaluation of the quality of the natural environment: approaches, methods, criteria and standards of comparison in ecotoxicology / Materials of the International Symposium. Moscow, October 25-28, 2016. МГУ. Москва GEOS 2016, с. 91-98
6. Korsunova Ts. Daish-Tsyreiova. Biological activity of chestnut soils of the dry-steppe zone of Buryatia under their cultivation (Specialty 03.00.27 — Soils) Abstract of the dissertation on the application of the academic degree of the candidate of biological sciences in Ulan-Ude — 2000, 19 p.
7. T.V Minnikova, G.V. Mokrikov, K.Sh. Kazeev, Yu.V. Akimenko, S.I. Kolesnikov. Evaluation of enzymatic activity of chernozems of the Rostov region under binary sowing of sunflower // Moscow Издательство РГАУ-МСХА Izvestiya ТСХА, issue 6, 2017. – с. 141-155
8. Pinaeva M.I. Agroecological justification of various methods of calculation of doses of mineral fertilizers and application of straw in the grain-steam link of field crop rotation 06.01.04 – agrochemistry Dissertation on the application of the academic degree of candidate of agricultural sciences Scientific supervisor: doctor с.-х. Science, professor L.A. Михайлова Perm, 2019, 162 p
9. Сложный компост and its influence on soil properties and productivity of agricultural cultures: monograph / Д.А. Antonenko. [и др.] ; under the editorship И. С. Belyuchenko. – Krasnodar: КубГАУ, 2015. – 181 с
10. Stakhurlova L.D., Stulin A.F. Biological properties of chernozems leached in a long experiment with corn / Soils in the biosphere: collection of materials of the All-Russian scientific conference with international participation dedicated to the 50th anniversary of the Institute of Soil Science and Agrochemistry of the Russian Academy of Sciences. 10–14 September 2018, г. Novosibirsk / отв. ed. A.I. Syso. – Tomsk: Publishing House of Tomsk State University, 2018. – Ch. II. - 458 p. (с. 145-148).

11. Titova, V.I. Agro- и biochemicheskie metody issledovaniya stostanio ecosystem: учеб. пособие для узов / В.И. Titova, Е.В. Dabakhova, М.В. Dabakhov; Nizhny Novgorod State. с.-х. academy. - N. Novgorod: Изд.-во ВВАГС, 2011. - 170 с.
12. Khaziev F.Kh. Methods of soil enzymology. M.: Nauka, 2005, 252 p.
13. Chugunova O.A. The influence of basic tillage methods on soil microbiota and spring barley productivity in the forest-steppe of the Middle Volga Region: Dissertation on the competition for the degree of candidate of agricultural sciences Scientific supervisor: candidate of biological sciences, professor Markovskaya G.K. Kinel – 2020. C. 168.
14. Amit Kumar, Muhammad Shahbaza, Evgenia Blagodatskaya, Yakov Kuzyakov, Johanna Pauscha. Maize phenology alters the distribution of enzyme activities in soil: Field estimates // A., Applied Soil Ecology (2018), 8 p. <https://doi.org/10.1016/j.apsoil.2018.02.001>
15. Haiyan Xu, Xiaodong Wu, Lin Zhao, Yuguo Zha, Tonghua Wu, Guojie Hu, Wangping Li and Yongjian Ding. Changes in soil enzyme activities under different vegetation types of the northern fringe of the permafrost regions in the Qinghai-Tibetan Plateau // Fresenius Environmental Bulletin. by PSP Volume 24 – No. 12 c. 2015, p. 4720-4728.
16. James Anthony Ippolito, David D. Tarkalson, and Gary A. Lehrsch. Zeolite Soil Application Method Affects Inorganic Nitrogen, Moisture, and Corn Growth // (Soil Sci 2011;176: 136-142.
17. Liu Guangming, Zhang Xuechen, Wang Xiuping, Shao Hongbo, Yang Jingsong, Wang Xiangping. Soil enzymes as indicators of saline soil fertility under various soil amendments // Agriculture, Ecosystems and Environment 237 (2017) 274–279. <http://dx.doi.org/10.1016/j.agee.2017.01.004>
18. Makhkamova D. Yu. Gypsiferous soils of Jizzakh steppe and their biological activity // J. Innovation Technical and technology Vol.1, No.2. 2020 p. 57-67.
19. M.C. Moscatellia, L. Secondia, R. Marabottinia, R. Pappa, S.R. Stazia, E. Maniab, S. Marinaria. Assessment of soil microbial functional diversity: land use and soil properties affect CLPP-MicroResp and enzymes responses // Pedobiologia - Journal of Soil Ecology. 2018. No. 66. P. 36-42.
20. Prem B. Parajuli, Sarah Duffy. Evaluation of Soil Organic Carbon and Soil Moisture Content from Agricultural Fields in Mississippi // Open Journal of Soil Science, 2013, 3, 81-90 <http://dx.doi.org/10.4236/ojss.2013.32009> Published Online June 2013 (<http://www.scirp.org/journal/ojss>)
21. Sneha S, Anitha B, Sahair RA, Raghu N, Gopenath TS, Chandrashekrappa GK, Basalingappa KM. Biofertilizer for crop production and soil fertility. Academia Journal of Agricultural Research. 2018; 6(8): 299-306
22. Stanislav Torma, Jozef Vilcek, Peter Adamisin, Emilia Huttmanova, Ondrej Hronec. Influence of natural zeolite on nitrogen dynamics in soil. Turkish Journal of Agriculture and Forestry. Turkish J Agric For (2014); 38: 739-744. doi:10.3906/tar-1311-13.
23. Yong-Tao Li, Corrine Rowland, Marc Benedetti, Fang-bai Li, Anne Pando, Patrick Lavelle, Jun Dai. Microbial biomass, enzyme and mineralization activity in relation to soil organic C, N and P turnover influenced by acid metal stress // Soil Biology & Biochemistry, 2009, 41, p. 969–970.
24. H. B. Zi, L. Hu, C. T. Wang, G. X. Wang, P. F. Wu, M. Lerdau & L. J. Ade. Responses of soil bacterial community and enzyme activity to experimental warming of an alpine meadow // European Journal of Soil Science, 2018. – 9 p. doi: 10.1111/ejss.12547.

25. Xuefeng Xie, Lijie Pu, Qiqi Wang, Ming Zhu, Yan Xu, Meng Zhang. Response of soil physicochemical properties and enzyme activities to long-term reclamation of coastal saline soil, Eastern China. *Science of the Total Environment* 607–608 (2017) 1419–1427. <http://dx.doi.org/10.1016/j.scitotenv.2017.05.185>.
26. Xuejuan Bai, Quanchao Zeng, Abbas Fakher, Yanghong Dong & Shaoshan An (2018): Characteristics of soil enzyme activities and microbial biomass carbon and nitrogen under different vegetation zones on the Loess Plateau, China, *Arid Land Research and Management*, 2018, 16 p.m. DOI: 10.1080/15324982.2018.1501621 To link to this article: <https://doi.org/10.1080/15324982.2018.1501621>.
27. Workat Sebnie, Enyew Adgo and Hailu Kendie. Characterization and Classification of Soils of Zamra Irrigation Scheme, Northeastern Ethiopia // *Air, Soil and Water Research* 2021 Volume 14: 1–12 doi.org/10.1177/117862212111026577.

UNDER PEER REVIEW