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Agro-Ecological Estimation of Various Fertilization Systems under Conditions of the Republic of Tatarstan

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Abstract

Producers of agricultural plants are increasingly marking a decrease in the responsiveness of cultivated plants to the mineral fertilizers applied to the soil. The explanation of this phenomenon can be the shift of limiting factors that determine the yield from mineral components in the soil to substances of organic and biological origin. The paper presents comparative data of the influence of mineral and organic fertilizer system on main biological indicators of the soil -- nitrogen transforming groups of microorganisms, total microbial number (TMN), and soil respiration. The change in total and mineral nitrogen in the soil is estimated. The novelty of the study is that organic fertilizers are used in amounts comparable to the doses of mineral fertilizers in physical weight -- 200 kg/ha. The application is carried out locally simultaneously with the seeding. As a result of the analysis, it has been found that ammonifiers (by 20.0--45 %), nitrifiers (by 30.0--46.7 %) numerically dominate in soil with organic fertilizers under all crops (corn, sunflower, soybean, sugar beet), the total microbial number is higher by 24.6--48.3 %. The intensity of carbon dioxide emissions (soil respiration) is also higher by 19.0--45.6 %. The intensity of biogeochemical processes in the soil and the related transformations of mineral nutrients, respectively and the provision of plants with them closely correlates with the number of valuable groups of microorganisms. The correlation coefficient between the number of ammonifiers and nitrifiers with the total nitrogen content in the soil under all studied crops in an organic fertilizer system is r=0.93.

Keywords: organic fertilizers, local application, soil biological activity

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1. Introduction

The need to include organic matter in the plant nutrition system in agronomic scientific community has never been challenged. However, a rare agricultural producer practices this fertilizer system due to insufficient technical equipment and low payback of

measures for the preparation of organic fertilizers, their transportation, application and incorporation into the soil. Exceptions are enterprises conducting complex crop and livestock production.

The relevant problem is to bring the use of organic fertilizers to the level of environmental and economic feasibility. As an example, we will cite the cases when an increase in the amount of used fertilizers does not lead to a relatively proportional increase in neither yield nor an improvement in the qualitative soil characteristics. Thus, the average concentration of mineral nitrogen in gray forest soils of Vladimir region did not significantly change under the action of double doses of organic fertilizers (28 t/ha). The average ammonium nitrogen value was 62.7 kg/ha, while the application of 14 t/ha provided a concentration of 61.8 kg/ha. The concentration of nitrate nitrogen also remained at relatively equal values with double fertilization of the soil -- 60.2 and 63.0, respectively [1].

Research of the staff of the Department of Agriculture Don Experimental Station of Oilseeds named after L.A. Zhdanov of All-Russian Research Institute of Oil Seeds show the importance of economically sound use of organic fertilizers. Studying the effect of biohumus on sunflower yield, the staff found that fertilizing for plowing at a rate of 4 t / ha gave a yield increase of 1.6 centners/ha. The use of the same biohumus for encrustation of seeds at a rate of 6 g/kg demonstrated an equivalent volume of yield increase of 1.5 centners/ha [2].

When developing a fertilizer system based on organic fertilizers, we should take into account the characteristics of the feedstock, the role of its qualitative preparation, imparting adaptability to manufacture for local application and the possibility of modification in accordance with the soil characteristics. Poultry manure is generally recognized and the most effective raw material. Its concentration of mineral substances is higher than in cattle manure: nitrogen -- by 3.6 times, phosphorus -- by 2.3 times, potassium -- by 1.7 times, calcium -- by 6.0 times, magnesium -- by 6.7 time. Crude protein value reaches 35.6 %. Malofeev V.I. in the textbook of ``Technology of manure thermal processing'' notes that the effect of dry granulated poultry manure is equivalent to the action of complex mineral fertilizer [3]. The effectiveness of granular organic fertilizers, introduced simultaneously with sowing in rows in 2016 under conditions of the Kabardino-Balkarian Republic (Tersky district), showed an average yield increase: corn -- by 21.5 %, soybeans -- by 45.3 %, spring barley by 37.7 % [4]. The study of the transformation mechanisms of mineral substances in the soil under the action of fertilizers, the assessment of their influence on microbiological parameters is a necessary condition for predicting the effectiveness of implemented fertilizer systems. In accordance with this provision,

we have carried out work to assess the influence of various fertilizer systems on the indicated soil characteristics.

2. Methods and Materials

An agro-ecological estimation of the studied fertilizer systems, which is based on the known parameters of fertility, was carried out on the experimental field of the Central Experimental Base of Tatar Agricultural Research Institute. The experiment was conducted within the framework of the International Field Days of Volga Region in 2016 in the Republic of Tatarstan.

Sowing was carried out in the second decade of May. The experimental field is located in the first agro-climatic region near the village of Bolshie Kabany of Laishevskii municipal district of the Republic of Tatarstan. The soil of the experimental site is gray forest heavy loamy, slightly humic. The humus content in this area is 3.2 %, and the soil acidity (pH) in the salt extract is 5.8 [5]. The area of the experimental sites in each variant was 50 m^2. Soil and plant samples for analysis were selected on July 02, 2016.

Objects of the study:

1. The mineral fertilizer system is represented by the complex mineral fertilizer of nitroammophoska (NPK 16-16-16). Application rate 200 kg/ha.
2. Bio-organic fertilizer system is represented by organic granular fertilizer based on fermented poultry manure. (NPK 4-4-3). Granules are enriched with microorganisms Pseudomonas asplenii VI 6 at a concentration of $2X10^7$. Application rate 200 kg/ha.
3. Corn hybrid ``KVS -- Klifton'', FAO175.
4. Soybean variety ``Miliausha'' (L 34/99).
5. Sunflower hybrid ``Oksi''.
6. Sugar beet. The names of the variety or hybrid have not been established.Subjects of the study:
7. Total microbial number of soil (TMN).
8. Soil respiration (carbon dioxide emission).
9. Number of ammonifiers in the soil.
10. Number of nitrifiers in the soil.

11. Number of denitrifiers in the soil.
12. Total nitrogen value in the soil.
13. Mineral nitrogen value in the soil.

Analytical work was carried out in the educational and scientific testing laboratory of FSBEI ``HE Stavropol State Agrarian University'' in accordance with the agreement **``On the creation and transfer of scientific and technical products'' No. 1291 dated July 22, 2016.**

Analyzes were carried out in accordance with accepted methodologies and regulatory documents:

Biological indicators.

The main physiological groups of soil microorganisms were studied according to the methodology of All-Russian Research Institute of Agricultural Microbiology by sowing a soil suspension of certain dilutions on selective nutrient environment (E.Z. Tepper, V.K. Shilnikova, G.I. Pereverzeva, 1979) with subsequent direct counting of colonies.

The number of ammonifiers was determined on meat-peptone agar (MPA), bacteria using mineral forms of nitrogen (nitrifiers) -- on starch-and-ammonia agar (SAA); the number of denitrifiers was taken into consideration on nitrate agar under anaerobic conditions (air is displaced with argon); soil bacteria on MPA environment, 10 times diluted with tap water. ``Soil respiration'' was determined by Galstyan method regarding quantitative changes in carbon dioxide in the soil atmosphere using wide-neck conical bulbs.

Agrochemical indicators.

GOST 26107-84 of Soil. Method for determination of total nitrogen.

GOST 26489-85 of Soil. Determination of exchangeable ammonium based on the method of Central Research Institute of Agrochemical Service.

GOST 26488-85 of Soil. Determination of nitrate based on the method of Central Research Institute of Agrochemical Service.

3. Results

When conducting an environmental-economic assessment of a particular crop production technology or fertilizer system, the accounting of quantitative changes in soil biological indicators, including the total microbial number (TMN) is an important parameter determining the direction of biochemical processes in it. Accordingly, the growth

of this indicator, expressed in digital units (CFU), indicates an increase in the production potential of the soil. Microbial activity under the influence of organic fertilizers grows to a greater extent than using only chemical fertilizers [6].

The experiment results confirm this statement.

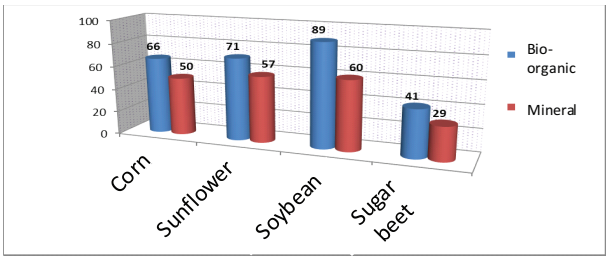

Figure 1: Effect of various fertilizer systems on the total microbial number, mln. CFU/1 g of soil.

Figure 1 demonstrates regular growth of the total microbial number in the soil under all studied cultures, fertilized by a bio-organic complex. The correlation dependence coefficient is r=0.95. First, the basis of the fertilizer -- thermally treated poultry manure is a highly concentrated organic substance that serves as an energy material for soil microorganisms. Second, microorganisms applied to granules also contribute to the growth of the total number of bacteria in the soil. The difference in TMN of bio-organic and mineral fertilizer systems depends on the crop. Thus, maximum excess is observed in the near-root zone of the soil under soybeans and sugar beet -- by 48.3 and 41.4 % respectively. The difference under corn and sunflower is 32 and 24.6 %.

The intensity of carbon dioxide emissions (soil respiration) is increasingly proposed to be considered as an integral indicator of soil fertility. There is a positive correlation between these parameters in both natural and cultural cenoses [7].

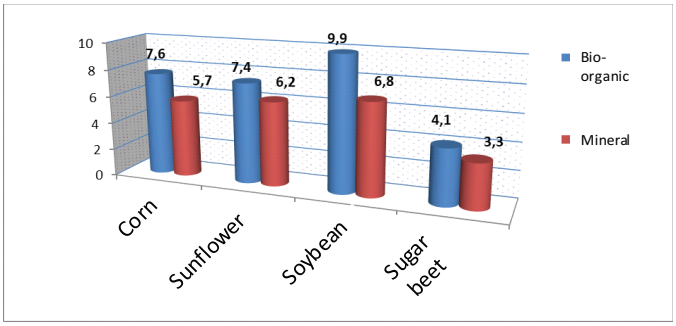

Figure 2: Effect of various fertilizer systems on soil respiration intensity, mg CO_2/10g of the soil per day.

Despite the fact that some researchers consider the existence of a close connection of soil respiration with the activity of microorganisms as delusion [8], native scientists argue the opposite [9, 10]. Moreover, with other equal agrochemical characteristics of the soil, the plants develop better with their greater enrichment with microbes [11].

The significant role of soil microorganisms in increasing the intensity of soil respiration can be judged by the correlation dependence between the data of Fig. 1 and Fig. 2. The correlation coefficient (r =) between the total microbial number and the soil respiration intensity is 0.99 in both bio-organic and mineral fertilizer systems (Table 1).

TABLE 1: Correlation dependence between TMN and soil respiration intensity.

Crop	Bio-organic fertilizers		Mineral fertilizers	
	TMN, mln. CFU/1 g of soi.	mg CO_2/10g of soil per day	TMN, mln. CFU/1 g of soil	mg CO_2/10g of soil per da
Corn	66	7,6	50	5,7
Sunflower	71	7,4	57	6,2
Soybean	89	9,9	60	6,8
Sugar beet	41	4,1	29	3,3
R =	0.990		0.996	

Influence pattern of organic fertilizers on the increase in TMN of the soil is also noted on the intensity of soil respiration in comparison with mineral fertilizers. In the soil under corn, the difference is 33.3 %, under sunflower -- 19.4 %, under soybean -- 45.6 %, under sugar beet -- 24.2 %. The presence of carbon dioxide in the soil is important for the occurrence of biochemical reactions. So, microbiologist S.N. Vernadskii found that autotrophic bacteria use carbon dioxide as carbon in 1887. The nitrification process is also accompanied by carbon dioxide fixation [12].

Comparing the fertilizer systems under study, it should be noted that bio-organic fertilizer had a greater impact on the growth of agronomically valuable groups of microorganisms --- ammonifiers and nitrifiers --- than the use of nitroammophoska. At the same time, the activity of denitrifiers involved in the conversion of mineral nitrogen compounds to gaseous ones turned out to be higher mainly when mineral complex fertilizers were added to the soil (Fig. 3).

Creating the conditions for increasing the number of ammonifiers and nitrifiers in the soil is directly related to the availability of nitrogen to crop plants. The literature notes a high correlation dependence between these indicators [13]. The excess in the number of ammonifying groups of microorganisms in the soil fertilized by bio-organic complex in relation to the soil with mineral fertilizer is 20 % under corn, 45 % -- sunflower, 32.3 % -- soybeans, and 41.7 % -- sugar beet. The trend of excess is repeated in relation to the nitrifying groups of microorganisms with a difference of 30 % (corn), 46.7 % (sunflower), 39.1 % (soybean), 50 % (sugar beet).

In contrast to the development of the above-mentioned microorganisms under the influence of the bio-organic fertilizer complex, the group of denitrifiers reduces its amount. So, agronomically unfavorable microorganisms -- denitrifiers, when using mineral fertilizers, exceed the number of those in soil enriched with organic fertilizer under corn by 66.7 %, sunflower -- 40 %, soybean -- 66.7 %. Their equivalent amount (3 mln. CFU/1gr of soil) is noted only under sugar beet. Similar data obtained on the basis of more in-depth studies allow us to consider organic fertilizers not only as a direct source of mineral components, but also as the most important energy material for beneficial soil microorganisms. This allows shortening not only the use of nitrogen mineral fertilizers, but also reducing its losses in the form of gaseous (N_2O) compounds [14].

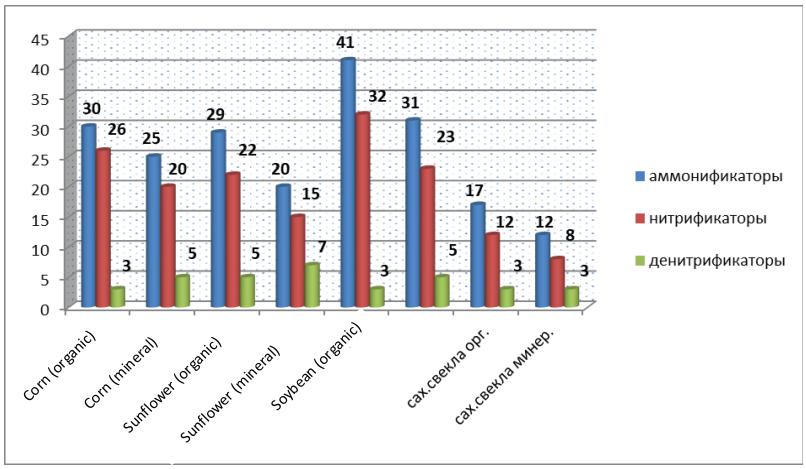

Figure 3: Effect of various fertilizer systems on nitrogen-transforming microorganisms in the soil, mln. CFU/1 g.Аммонификаторы- ammonifiers, нитрификаторы -- nitrifiers, денитрификаторы -- denitrifiers.

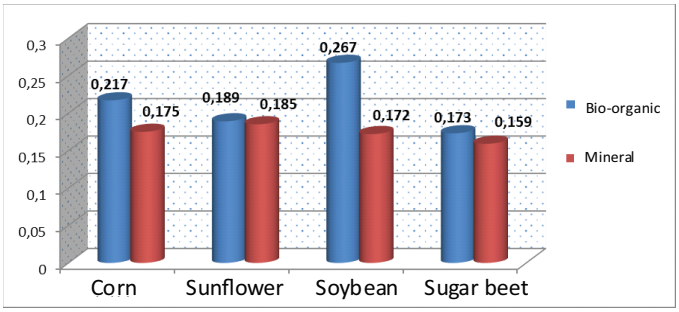

Figure 4: Effect of various fertilizer systems on total nitrogen value in the soil, %.

Nitrogen nutrition of plants is carried out on a special, different from all macro and microelements in the system. As a rule, the provision of plants with mineral elements is achieved due to their mobilization from soil reserves or applied fertilizers. Moreover, an increase in their gross content in the arable layer can be achieved mainly due to the biolifting mechanism from the lower horizons by a powerfully developed root system. In the case of the gross supply of nitrogen in the soil, the source of its biological

accumulation is nitrogen of atmospheric air, the amount of which can be accumulated in incomparably large quantities than a plant is able to assimilate. Subsequent provision of plants with nitrogen is achieved both by fertilizing and by creating conditions for the transformation of soil reserves into mineral nitrogen compounds. In this regard, a deeper study of the nitrogen transformation mechanisms, accounting of potential and current security, expressed in digital units, will make it possible to choose the most effective fertilizer system. Figure 4 shows how we can control the features of nitrogen regime in the soil for these purposes.

The initial volume of nitrogen entering the soil within 200 kg/ha of bio-organic fertilizers was only 8 kg/ha. It was 4 times more -- 32 kg/ha with nitroammophoska. However, in 45 days, an increase in total nitrogen in the first case is traced in the near-root zone of the studied cultures. In the zone of corn roots development, the increase is 24 %, soybeans -- 55 % and sugar beet -- 8.8 %. Data for sunflower -- 2.2 % are within the margin of error.

A similar trend is observed in mineral forms value of nitrogen in the same soil samples (Fig. 5). The mineral nitrogen value in the near-root zone of corn exceeds by 117 %, soybeans -- 5.6 %, sugar beet -- 144 %. The concentration of mineral nitrogen under sunflower is 4.5 % lower.

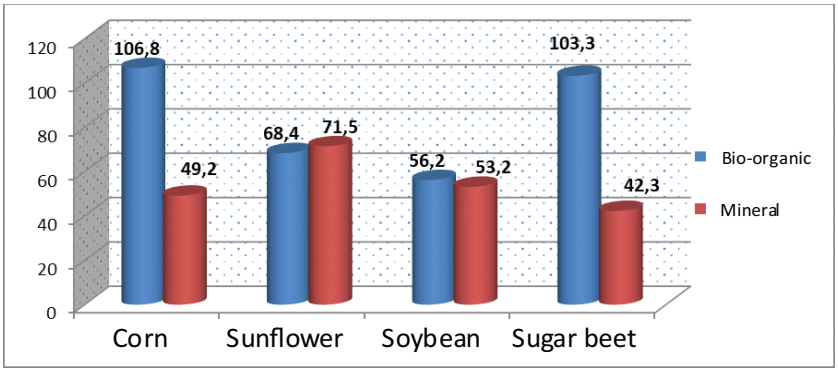

Figure 5: Effect of various fertilizer systems on mineral nitrogen value in the soil, mg/kg of soil.

Figures 4 and 5 show that the amount of total and mineral nitrogen does not significantly change in the near-root zone of the sunflower depending on the fertilizer system in this time period (45 days). But at the same time, the activity of microorganisms transforming nitrogen in the soil is highest with respect to other cultures (Fig. 3). In this case, we can conclude that due to the biological characteristics of the sunflower, the activity of ammonification and nitrification processes manifested much later than under corn, soybean and sugar beet. Accordingly, there was no accumulation of the accompanying activity of the nitrogen product by this time. Data analysis confirms the generally

accepted view that an effective fertilizer system cannot be universal. Consideration of the biological characteristics of crops, soil characteristics and parameters of selected fertilizers is the most important condition for the development of an efficient nutritional system for cultivated plants that meets the principles of environmental and economic feasibility.

4. Conclusion

D.N. Prianishnikov, paying great attention to the use of organic fertilizers, referred not only to improving the physical properties of the soil, but also to their effect on microbiological activity in it. He wrote: ``... no matter how large the production of organic fertilizers is in the country, manure will never lose its value'' and ``... without proper organization of its use, real rational use of mineral fertilizers cannot be established'' [15]. A comparative analysis conducted in our work confirmed the high potential of organic fertilizers in improving the fertilizer system of agricultural plants through the impact on the ecological parameters of the soil. Innovation, which should be inherent in the agricultural production of the 21st century, consists in the technological preparation of organic fertilizers (the choice of concentrated raw materials, disinfection, enrichment, the possibility of local application), in combining the results of agrochemical science with the achievements of microbiology and obeying the requirements of economic feasibility of their use. In fact, the development of fertilizer systems that combine the three components of any soil -- mineral, organic and microbiological, is the way of evolutionary development of agrochemical science. And as a result, the expansion of the list of indicators of soil fertility at the expense of biological indicators allows us to more objectively assess its potential, which leads to lower costs in crop production and to increase its profitability.

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