AGROECOSYSTEM STABILITY IN SPRING WHEAT CROPS WITH THE APPLICATION OF FERTILIZERS AND MICROBIAL BIOLOGICAL PRODUCTS

A A Alferov, L S Chernova

Pryanishnikov All-Russia Research Institute for Agrochemistry, Moscow, 127550 Russia

e-mail: alferov72@yandex.ru

Abstract. The formation of spring wheat biomass on sod-podzolic soil is carried out mainly due to soil nitrogen, the share of which reaches 1/3 of the total removal of the element when using mineral fertilizers. Inoculation of spring wheat seeds with biologics of rhizosphere microorganisms increases the nitrogen content of fertilizers to 7.3%, increases its immobilization by 5.9-6.7% and reduces losses by 7.4-13.9%. The stability of the agroecosystem is characterized by nitrogen flows. During the growing season of spring wheat with a hydrothermal coefficient of 1.55-1.72, the amount of mineralized nitrogen (mineralization (M)), depending on fertilizers, reaches 9.4-11.1 g/m², while the reimmobilized nitrogen (reimmobilization (RI)) – 2.2-3.1 g/m², net-mineralized (net-mineralization (N-M)) – 6.8 - 8.0 g/m². The use of nitrogen fertilizers and biological products leads the agroecosystem to the resistance mode (the maximum permissible level of exposure) (RI : M = 27-28%, N-M : RI = 2.5-2.7).

Keywords: spring wheat, microbial biological products, agroecosystem stability, nitrogen fertilizer.

1. Introduction

The agroecosystem acts as an integral, open, dynamic system, the functioning of which depends on changes in environmental factors and the level of anthropogenic load [1]. In specific soil and climatic conditions, the anthropogenic factor in the agroecosystem is realized in the form of a direct impact on its structure, food chains, energy and nutrient cycles, as a result of which the regimes in the soil, the number and species diversity of plants and microorganisms change, and the agroecosystem itself acquires a number of specific characteristics inherent in a specific type of human economic activity [2-4]. Among the aspects of the development of the agroecosystem, research on carbon and nitrogen is important. In this regard, the knowledge of the mineralization-immobilization turnover of nitrogen in the soil is important for understanding the subsurface nitrogen cycles and solving practical problems, such as achieving synchronization of the processes of accumulation of mineral nitrogen in the soil and its assimilation by agricultural crops, which prevents excessive accumulation of nitrates in the environment, reduces gaseous nitrogen losses and maintains the stability of the agroecosystem [5, 6].

The aim of the study is to determine the parameters of the nitrogen cycle of fertilizers and soil during the cultivation of spring wheat inoculated with microbial biological products on sod-podzolic soil and to assess the stability of the agroecosystem.
2. Research methodology

The effect of biological products of rhizosphere microorganisms and nitrogen fertilization on the N balance and the identification of the role of various sources of nitrogen nutrition of plants in the formation of spring wheat yield was studied in 2018-2019 in a microfield experiment in vessels without a bottom with an area of 0.018 m², where 10 spring wheat plants were grown (Triticum aestivum L.) varieties Zlata. The predecessor of spring wheat is buckwheat. Ammonium nitrate (15NH415NO3), enriched with labeled nitrogen 15N (54.04 at.%) were introduced in the spring when the vessels were packed at a dose of 180 mg per vessel, which corresponds to 4.5 g/m², or 45 kg N/ha. Double superphosphate and potassium chloride were used as a background in doses P30K45. Agrochemical indicators of the soil of the experimental site: humus content (according to Tyurin) – 1.91-2.04%, movable forms P2O5 and K2O (according to Kirsanov) - respectively 125.1-140.8 and 129.0-166.0 mg/kg of soil, pHKCl 5.6-5.7; the experiment was repeated 4 times. In order to better perceive the results of the experiment, the corresponding indicators are given in terms of g/m². On the day of sowing, spring wheat seeds were treated with biological products: Rhizoagrin (RA), created on the basis of strain 204 belonging to the genus Agrobacterium radiobacter; CL-10 based on a strain of associative rhizobacteria belonging to the genus Pseudomonas sp., isolated from the rhizosphere of barley plants and has a high growth-stimulating activity; 17-1 based on a strain of associative rhizobacteria belonging to the genus Pseudomonas sp., isolated from the rhizosphere of barley plants and has a high antifungal activity in relation to the spectrum of phytopathogenic fungi, as well as a high growth-stimulating activity. Microbial biological products containing 5-10 billion bacterial cells in 1 g are powdery peat substrates with a moisture content of 45-50%. The strains take root well in the rhizosphere of cereal crops [7].

To calculate the balance and fluxes of soil nitrogen in the system soil - microorganisms - fertilizers - plants - atmosphere, we used the isotope 15N data based on the proportionality in the distribution of labeled and mineralized soil nitrogen [1, 8]. Calculations were carried out according to the formulas:

\[ N_c = N_a \cdot \frac{15N_c}{15N_a}; \quad N_d = N_a \cdot \frac{15N_d}{15N_a}; \]
\[ M = N_a + N_b + N_c + N_d; \quad N-M = N_a + N_b + N_d; \]
\[ RI = M - N-M, \]

where the nitrogen flows: a – plant use; b – residual mineral in the soil; c – immobilized; d – losses; M – mineralized soil nitrogen; N-M – net mineralized soil nitrogen; RI – reimmobilized soil nitrogen.

Weather conditions varied over the years of research. In 2018, weather conditions were characterized by an uneven distribution of precipitation - a lack in May, August and a significant excess in July (267% to the monthly norm) with an average monthly temperature of the growing season 1.1 °C higher than the climatic norm, the hydrothermal coefficient (HTC) was 1.72. Most of the growing season in 2019 was characterized by increased precipitation, with the exception of June, HTC = 1.55.

3. Results and discussion

Studies carried out using labeled nitrogen fertilizers 15N, showed that on soddy-podzolic soil, the nitrogen pool in spring wheat crops is formed at the expense of soil nitrogen (1/3) (Table 1.). The application of nitrogen fertilizers enhances the mineralization of soil organic matter, as a result of which the availability of soil nitrogen to plants increases and the total nitrogen removal by the biomass of spring wheat increases (1.9 times compared with the variant P30K45). Spring wheat plants consume the maximum amount of nitrogen in fertilizers and soil when applying ammonium nitrate and using biological products (2.0-2.2 times). Inoculation of spring wheat seeds with biological preparations of rhizosphere microorganisms increases the utilization factor (UF) of fertilizer nitrogen to 7.3%, increases its immobilization by 5.9-6.7% and reduces losses by 7.4-13.9%.

Agrophytocenosis of spring wheat when seeds were inoculated with biological products based on rhizosphere microorganisms functioned in a more stable mode compared to the option of applying one nitrogen fertilizer. Greater stability was achieved, first of all, due to better use of mineral fertilizer nitrogen (by 4-20%), increasing its immobilization (by 23-26%) and reducing its losses (by 20-37%). At the same time, the indicators of the soil nitrogen cycle when using microbial biological products are at a higher level of environmental sustainability. The calculation of the integral estimate showed that...
against the background NPK inoculation of spring wheat with biological products based on Agrobacterium radiobacter and rhizobacteria belonging to the genus Pseudomonas sp., contributed to the transition of the agroecosystem to a state of resistance, the level of exposure is the maximum permissible (RI: M = 27-28%, N - M: RI = 2.5-2.7), while the introduction of only nitrogen fertilizers against the background of RA leads to adaptive depletion of sod-podzolic soil, and the impact level is critical (RI: M = 22%, N - M: RI = 3.5).

Table 1. Fertilizer nitrogen balance, soil N fluxes, and agroecosystem stability upon inoculation of spring wheat with microbial biological products

| Indicator | P_{30}K_{30} + N_{45} | B + N_{45} + RA | B + N_{45} + Strain CL10 | B + N_{45} + Strain 17-1 |
|-----------|------------------------|------------------|--------------------------|--------------------------|
| Total removal of N by plants (grain + straw), g / m² | 4,81 | 5,03 | 5,66 | 5,57 |
| Used by plants N fertilizers, g / m² | 1,66 | 1,78 | 1,99 | 1,73 |
| Immobilized fertilizer N, g / m² | 1,14 | 1,41 | 1,44 | 1,41 |
| Gaseous losses of N fertilizers, g / m² | 1,70 | 1,31 | 1,07 | 1,36 |
| Carrying out of soil N by plants, g / m² | 3,15 | 3,25 | 3,67 | 3,84 |
| Residual N soil, g / m² | 1,10 | 1,20 | 1,15 | 1,12 |
| Immobilized / reimmobilized soil N, g / m² | 2,17 | 2,57 | 2,66 | 3,13 |
| Gaseous losses of N soil, g / m² | 3,23 | 2,39 | 1,97 | 3,02 |
| Mineralized soil N, g / m² | 9,65 | 9,41 | 9,45 | 11,11 |
| Net mineralized soil N, g / m² | 7,48 | 6,84 | 6,79 | 7,98 |
| Reimmobilized soil N, g / m² | 2,17 | 2,57 | 2,66 | 3,13 |
| RI : M, % | 22 | 27 | 28 | 28 |
| N - M : RI | 3,5 | 2,7 | 2,6 | 2,5 |

Note: Total removal of N by plants (grain + straw) in the variant P_{30}K_{30} (background) made up 2,55 g/m².

4. Conclusion
In the studies carried out (using nitrogen fertilizers labeled $^{15}$N) the size of the nitrogen cycle of fertilizers and soil during the cultivation of spring wheat on sod-podzolic soil has been determined. With the size of soil nitrogen mineralization 9.45 - 11.11 g / m² inoculation with biological products based on rhizosphere microorganisms increases its immobilization. The use of biological products with nitrogen fertilizers increased the participation of nitrogen (fertilizers, soil) in the production process and in increasing the stability of the agroecosystem when growing spring wheat, transferring it from a state of adaptive depletion to a mode of functioning called resistance.

References
[1] Pomaskina L.V. A new integral approach to assessing the modes of functioning of agroecosystems and environmental regulation of anthropogenic load, including technogenic soil pollution // Advances in modern biology. – 2004. – Tom. 124. – № 1.– p. 66-76.
[2] Sichev V.G., Sokolov O.A., Zavalin A.A., Shmyreva N.Ya. The role of nitrogen in the intensification of the production process of agricultural crops. Volume 2. Environmental aspects of the role of nitrogen in the production process. – M.: ARRIA, 2012. – 272 p.
[3] Sokolov O.A., Zavalin A.A., Sichev V.G., Shmyreva N.Ya., Tsyricov L.N. Nitrogen fluxes in agrophytocenosis on eroded soils. – M.: ARRIA. – 2015. – 96 p.
[4] Zavalin A.A., Sokolov O.A. Nitrogen fluxes in the agroecosystem: from the ideas of D.N. Pryanishnikov to the present day. – M.: ARRIA, 2016. – 591 p.

[5] Mircin B.M., Naymova L.G., Haziahmetov R.M. Agroecosystem function management: environmental aspect // Advances in modern biology. – 2001. – T. 121. – №3. – p. 227-240.

[6] Pomaskina L.V. Assessment of the influence of climatic factors and pollution of alluvial soils with heavy metals on the functioning of agroecosystems of the Baikal region // Agrochemistry. – 2018. – № 4. – p. 78-87.

[7] Zavalin A.A. Biologicals, fertilizers and crops. – M.: Publishing house ARRIA, 2005. – 302 p.

[8] Pomaskina L.V., Cotova L.G., Zorina S.Yu., Ribacova A.V. Comparative assessment of the state of agroecosystems on different types of soils of the Baikal region, contaminated with fluorides of aluminum production // Soil science. – 2008. – № 6. – p. 717-725.