Productivity of winter rye in terms of the use of bio-organic nano-fertilizer Nagro

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Abstract. The results of the study carried out in the northern forest-steppe foothills of the South-East of Western Siberia in 2014-2017 in order to assess the impact of seed treatment and winter rye crops for vegetation by bioorganic nano-fertilizer NAGRO on the grain yield and quality and to identify the most effective option are presented. Vlada and Tetra short varieties were studied, treated according to six experimental options. Two types of biofertilizers were used: bioenergetics NAGRO – for daily treatment of seeds and crops and NAGRO universal – for treatment of crops during vegetation. Control – seeding without the use of bio-fertilizer. Pre-sowing seed treatment carried out by NAGRO bioenergetics with the norm 1 l/t, the crops by NAGRO universal with the norm 1 l/ha and by the bioenergetics – 0.2 l/ha. Working solution volume is 250 l/ha. The increase in yield on the variants of the experiment with respect to the control of Vlada varieties by 7 – 20%, Tetra short varieties by 7 – 15%. More efficient yields were the crops with the treatment options in the variety of Vlada – three (seed treatment with bioenergetics, 1st treatment on vegetation – bioenergetics in the phase of tillering in the spring, the 2nd processing – universal in the earing phase); the varieties of Tetra short - two (seed treatment with bioenergetics, 1st treatment on vegetation – universal + bioenergetics in the phase of tillering in the spring, the 2nd treatment – universal in the earing phase). The greatest number of falls was observed in Tetra short variant two, for Vlada - in variant three.

1. Introduction

Nowadays, if there is a necessity of transition to agricultural technologies that reduce the anthropogenic load, of reduction or refusal from the mineral fertilizers and herbicides, it is appropriate to use new generation fertilizers, the so-called nano-fertilizers, providing improvement of conditions of development of plants, increased quantitative and qualitative productivity of agricultural products, while providing a positive impact on the environment [1].

According to Rahale G.S. “in order to improve the efficiency of nutrient use and overcome the chronic problem of eutrophication, nano-fertilizer may be the best alternative. Nano-fertilizers regulate the release of nutrients depending on the needs of crops, and are also more effective than conventional fertilizers. Slowly controlled released fertilizers can also improve soil quality by reducing the toxic effects associated with excessive fertilizer use” [2]. Under its influence, drought resistance of plants increases [3], stimulate the process of photosynthesis [4], provide an increase in yield and improve the quality of agricultural products [5, 6]. The use of natural stimulants in crop production attracts more and more attention of farmers [7]. A number of researchers show the effectiveness of application in the technology of cultivation of Bioorganic nano-fertilizer Nagro [8, 9].
The purpose of this study was to evaluate the effect of treatment of seeds of winter rye crops by the vegetation of Bioorganic nano-fertilizer NAGRO on yield and grain quality in the conditions of the climatic zone of the northern forest-steppe of the foothills of the South-East of Western Siberia (Kemerovo region).

2. Materials and methods of the research

Field experiments were carried out in 2014 – 2017 years in the northern forest-steppe foothills of the South-East of Western Siberia (Kemerovo region). The soil of the experimental site is the leached humus, medium loamy, medium for particle size distribution on heavy loam granulometric composition with the following agrochemical characteristics: humus content of 8.9% ("Russian Standard GOST 26213 – 91. Soils. Methods of determination of organic matter. M.: Publishing house of standards, 1992. 8 p."). the provision of mobile forms of phosphorus and potassium (by Chirikov) 140 and 154 mg/kg of soil, respectively ("Russian Standard GOST 26204-91 Soil. Determination of mobile compounds of phosphorus and potassium by the method of Chirikov in the modification of the Central Institute of agrochemical services. M.: Publishing house of standards, 1992. 8 p."). The pH of slightly acidic salt extract (6.0) ("Russian Standard GOST 26483 – GOST 26490-85 Soil. Determination of pH of salt extraction, exchangeable acidity, exchangeable cations, nitrate, ammonium exchange and mobile sulfur by the Central Institute of agrochemical services. M.: Publishing house of standards, 1985. 6 p.").

Bioorganic nano-fertilizer NAGRO is characterized by a set of positive properties on the impact on agricultural crops and the environment: it stimulates the development of plants, increases immunity, is an antistressant, helps to reduce doses of plant protection products, restores soil fertility, increases productivity and improves product quality. Bio-fertilizer NAGRO is not subject to state registration, as it does not fall under the law № 109 of the Federal law, as there is a letter of the Rosselkhoznadzor № FS-AS-3/11757. Bio-fertilizer is allowed to be used on soils of ecological agriculture, it has the certificate of the European Union of the Commission "ECOAGROS" [10, 11]. In the experiment used two forms of nano-fertilizers, produced in the “NGOs BioPlant” in Podolsk: NAGRO bioenergetics – for daily treatment of seeds and NAGRO universal for the treatment of vegetative plants.

The objects of the study were varieties of winter rye Vlada and Tetra short. The scheme of experience consisted of six options against the background of control:
1. Seed treatment with bioenergetics, treatment of vegetation: universal + bioenergetics in the phase of tillering in spring;
2. Seed treatment with bioenergy, 1st treatment for vegetation – universal + bioenergetics in the tillering phase in the spring, 2nd treatment universal in the earing phase;
3. Seed treatment with bioenergetics, 1st treatment on vegetation – bioenergy at the tillering stage, 2nd treatment by universal in the earing phase;
4. Treatment of vegetation: universal + bioenergetics in the phase of tillering in spring;
5. Treatment of vegetation: 1st – universal + bioenergetics in the phase of tillering in the spring, 2nd – universal in the phase of earing;
6. Treatment of vegetation: 1st – bioenergetics in the phase of tillering in the spring, 2nd – universal in the earing phase.

Control - crops without the use of bio-fertilizer.

Pre-sowing seed treatment carried out by the bioenergetics with norm 1 l/t, the crops by universal bio-fertilizer with the norm 1l/ha and the bioenergetics – 0.2 l/ha. Volume of working solution seed treatment – 10 l/t, the crops 250 l/ha.

The experience is based on a three-fold repeat, the location of the plots is rendered, the size of 100 m². Agricultural cultivation was carried out in accordance with the zonal recommendations, as a precursor used pure steam. Pre-sowing treatment of seeds was carried out by MAROLEX MINI 1000 the 7 days before sowing. Sowing was carried out by seeder grain-flow press -3.6 A. Rye plants were treated with a knapsack sprayer ECHODM-4610. Cleaning was carried out by combine harvester “Yenisei-1200” in the phase of full ripeness. Yields were taken into account by the continuous method based on standard humidity and purity. The number of falls was determined in accordance with GOST
27676-88 ("Russian Standard GOST 30498-97. Grain crop. Determination of the number of falls. M.: printing and publishing complex - Publishing house of standards, 1997. 16 p."). Mathematical processing was carried out by the method of dispersion analysis, the effectiveness of seed treatment options and sowing was carried out on the basis of bioenergetic assessment.

The vegetation conditions of the summer period, estimated by the value of the hydrothermal coefficient - HTC, 2015 and 2016 years were characterized as arid (HTC = 0.38–0.89), with the exception of May 2015 and July 2016 with HTC = 1.19 and 1.40, respectively. In 2017, there was a shortage of moisture in May and June (HTC = 0.82 and 0.76, respectively), hydrothermal conditions in July and August were close to the optimum for the needs of rye plants (HTC = 1.42 and 1.07, respectively) (figure 1).

Figure 1. Hydrothermal coefficient of the vegetation period.

Weather conditions of the winter period (October–March) 2014-2015 years were characterized by warm weather (-9.8 °C), an abundance of precipitation – 147.3 mm, exceeding the norm by 29 %. The minimum temperature at the depth of the tillering node was observed in February (-12.3 °C), in March -7 °C. For 2015-2016 years October and November were warmer by 4.8 °C and moistened by 0.9 mm in comparison with the same period of 2016-2017. December for 2015-2016 and 2016-2017 was warmer than the norm by 9.8 and 4.4 °C, characterized by an abundance of precipitation exceeding the norms in 2.5 and 2.2 times respectively. The minimum temperature of the tillering node in 2015–2016 was observed in November -10.0 °C, in March -4.4 °C, for 2016-2017, it was noted in February -10.7 °C, and in March -7.4 °C (figure 2).

Figure 2. Minimum temperature at the depth of winter wheat tillering node (°C).
The wintering conditions of the study years for winter rye plants were satisfactory. The minimum temperature of the tillering node did not reach the critical -18 °C for winter rye [20]. The most favorable conditions were observed in the winter of 2015-2016, the temperature in March was warmer by 2.6–3.0 °C compared to the conditions of the same period of 2014-2015 and 2016-2017.

3. Results and discussion
During the years of the study, an average increase in yield was found in all variants of the experiment with respect to control of Vlada variety by 0.20–0.66 t/ha (7-20 %), Tetra short variety – 0.19–0.51 t/ha (7-15 %) (figure 3, 4).

![Figure 3](image3.png)

**Figure 3.** Crop yield (t/ha) of winter rye of Vlada variety depending on the exposure of bio-fertilizer NAGRO

![Figure 4](image4.png)

**Figure 4.** Crop yield (t/ha) of winter rye of Tetra short variety depending on the exposure of bio-fertilizer NAGRO.

The highest yield was provided the sowing of treated bio-organic fertilizer NAGRO, varieties Vlada for variant three: seed treatment with bioenergetics, 1st treatment on vegetation – bio-energetics in the phase of tillering in the spring, the 2nd treatment is a universal in the phase of earing; the varieties of Tetra short for variant two: seed treatment with bio-energetics, 1st treatment on vegetation – universal + bio-energetics in the phase of tillering in the spring, the 2nd processing – universal in the earing phase. At
the same time, Vlada’s yield reached 3.37 t/ha, exceeding the control by 0.66 t/ha (on 20 %), Tetra short, respectively, 3.38; 0.51 t/ha (15 %).

Hydrothermal conditions of the year of the study had a significant impact on the dependence of yield on bio-fertilizer treatments. In arid conditions of 2015 and 2016 (HTC vegetation period, respectively 0.69 and 0.83), the yield of both varieties on crops of all variants of the experiment was higher than the control sowing. In the same years, there was a more pronounced positive effect of bio-fertilizer on yield. The greatest increase in yield reached the varieties Vlada – 0.58, Tetra short – 0.53 t/ha. In wetter conditions in 2017 (HTC of vegetation period was 1.02) separate variants of the experiment was inferior to the yield level to control with less efficiency. The maximum excess yield was 0.13 in Vlada varieties, varieties of Tetra short – 0.20 t/ha. Higher yields of both varieties in all variants of experience, including control crops, was formed in 2016. Comparison of hydrothermal conditions of the summer vegetation period of winter rye by years of study shows that in 2016 the HTC for the entire vegetation period (May – August) was 0.83 (figure 1). The conditions of the summer period of 2015 were more arid, 2017 – more favorable in the ratio of heat and moisture (HTC = 1.02). The analysis of hydrothermal conditions in dynamics by months shows that in May–July 2016 and 2017 the studies were quite close in terms of HTC values. August 2016 (HTC = 0.53) was more arid in comparison with the terms and conditions of this month 2015 (HTC = 0.78), and especially 2017 (HTC = 1.07).

Apparently, the pronounced effect on the level of productivity lies in the conditions of wintering of winter rye plants. In particular, the most important condition for winter rye is the temperature of the tillering node. It should be noted that in comparison with 2015 and 2017, in 2016 there was a more favorable temperature of the tillering node in most months of the winter period, with the exception of November and December. In particular, the temperature regime of October 2016, when the temperature of the tillering node was +0.6 °C against -0.1 and -0.7 °C in 2015 and 2017, could have a positive impact on the development of plants, respectively, that could allow form more developed plants. More favorable in 2016 was the temperature in March and April (+0.1 °C, respectively). Lowering the temperature of the tillering node from November to February (from -7.4 to -10.0 °C) was leveled by sufficient snow cover.

In response to the processing of the bio-fertilizer NAGRO of the falls number of winter wheat varieties Vlada and Tetra short were close (figure 5). Both varieties have a positive effect of drugs on the sowing variants from the second to the fifth, with an increase relative to the control of 5 – 23 %.

![Figure 5. The number of fall varieties of winter rye from the processing of bio-fertilizer NAGRO, 2015-2017.](image)
The greatest increase in the number of falls in the variety of Vlada was observed in crops treated by bio-fertilizer NAGRO under variant three, under its value in average for four years was 186 c, which is in accordance with the requirements of GOST R 53049-2008 ("Russian Standard GOST R 53049-2008. Rye. Technical conditions. M.: STANDARTINFORM, 2009. 8 p.") corresponds to the grain of the second class of quality, the variation in years from 112 to 254 c. In the Tetra Short variety, the largest number of drops was characterized by grain from crops grown under variant two with a drop number of 217 c, corresponding to the grain of the first quality class, varying from 150 to 292 c. There was a strong variation in the number of drops by years (V = 22 - 66 %) and by variants (V = 64 - 68 %).

Energy intensity and energy costs for bio-organics fertilizer NAGRO used in the study were calculated based on the recommendations of this technique: at the rate of 0.015 GJ/kg of active substance per 1 hectare norm. The energy cost of cultivation of winter rye varieties Vlada over the years of research on the variants of experience ranged from 3.17 to 3.67 GJ/t of grain and was lower than the cost of control variant (3.93 GJ/t of grain).

Energetically more profitable was the production of grain of this variety according to the variant of experience three, in which the minimum energy cost was observed – 3.17 GJ/t, the sowing efficiency – 10.11 (figure 6).

![Figure 6. Sowing efficiency factor.](image)

The cost of cultivation of varieties of Tetra short, by varying options of the experience of 3.16 to 3.56 GJ/t of grain, the lowest was in the crop under variant two, accounting for 3.16 (sowing efficiency 10.12) against the control of 3.71 GJ/t (sowing efficiency 8.62). Several costly relative to the most cost-effective variants of crops studied varieties, but also has an advantage in comparison with the control, there were options in the variety of Vlada – one and two, varieties of Tetra short - one and three.

4. Conclusions
In the area of the Northern forest-steppe foothills of the South-East of Western Siberia in the cultivation of winter rye against the background of Bioorganics fertilizer NAGRO revealed an increase in yield relative to the control of the variety Vlada by 7-20 %, Tetra short by 7– 15 %. More efficient yields was the crop in the processing options for the variety of Vlada – three (seed treatment with bioenergetics, 1st treatment on vegetation – bioenergetics in the phase of tillering in the spring, the 2nd treatment is a
universal in the phase of earing; the Tetra short variety has – two (seed treatment with bioenergetics, 1st treatment for vegetation – universal + bioenergetics in the tillering phase in the spring, 2nd – universal treatment in the earing phase). On average, during the years of the study, the yield reached varieties in Vlada of 3.37 t/ha (the energy cost to 3.17 GJ/t, the efficiency of the sowing 10.11), for the control respectively of 2.71 t/ha (the energy cost of 3.93 GJ/t, the efficiency of the sowing of 8.14); in varieties of Tetra short of 3.38 t/ha (the energy cost of 3.16 GJ/t, the efficiency of the sowing 10.12), on the control of 2.87 t/ha (the energy cost of 3.71 GJ/t, the efficiency of the sowing of 8.62).

The greatest increase in the number of falls in Tetra short variant two (217 - grain of the first quality class, for years from 150 to 292), in Vlada varieties on crops of variant three (186 - grain of the second quality class, for years from 112 to 254).

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