Agroecological role of biohumus on sod-podzolic soil during irrigation of the rump-timothy grass mixture

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Abstract. It has been established that it is possible to increase the productivity of grasslands on sod-podzolic soil with the introduction of biohumus against the background of irrigation. The optimal variant of the experiment with the introduction of vermicompost at the rate of 8 t/ha. The research results revealed an increase in the content of basic nutrients in the soil by 0.2 ... 4 mg/100 g of soil, activation of the cellulose-degrading activity of the soil twice, which was characterized as strong on the Zvyagintsev scale. The content of organic matter in the soil increased to 0.28 t/ha. The plant density increased by 1.5 times, the height – 2 times, the yield of the grass mixture increased on average to almost 5 t/ha, the quality of products improved, which corresponded to the zootechnical norm in almost all parameters. The cost of production amounted to 2.04 rubles/kg, conditionally net income – 3.64 rubles. In the summer of 2019, the research results passed the first year of approbation at Igor Vyacheslavovich Belousov LLC on an area of 1.5 hectares. The yield was 4.8 t/ha of dry matter, which is 31% higher than the control option – traditional technology.

1 Introduction

Most of the natural meadows in Russia have low productivity, low quality of herbage. Hayfields and pastures are used haphazardly or removed from agricultural use [1-5]. It is possible to increase the productivity of meadows by improving them, for example, by introducing vermicompost, which is an organic fertilizer, obtained as a result of the processing of organic waste by worms under conditions of artificial cultivation [6-12]. Worms greatly influence the growth, development and productivity of agricultural crops. They participate in multi-stage processes of decomposition of organic residues in the soil and their transformation into forms accessible to plants. [2, 11].

2 Materials and methods

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The purpose of the research is to study the effectiveness of vermicompost during irrigation of the rump-timothy herb mixture. Research objects – perennial grasses and sod-podzolic soil.

Scientific novelty – for the first time, the agroecological features of the action of biohumus during irrigation of the brome-timothy grass mixture on sod-podzolic soil were studied, taking into account the soil and climatic features of the Non-Black Earth Region. The practical significance of the work consisted in the development of scientifically grounded proposals for the farms of the Ryazan region due to the establishment of the optimal parameters for the impact of biohumus on soil and plants.

The northern territory of the Ryazan region is represented by the Meshchera lowland with a relief that is a combination of moraine-water-glacial and lacustrine-alluvial plains. Groundwater occurs at a depth of 1.5-5 m [3, 4]. Ryazan Region is located in a zone of sufficient moisture, however, during the growing seasons, plants often experience a lack of soil and atmospheric drought. On the territory of the region, droughts occur periodically, once every five or ten years, extremely dry years are noted– once every 30 years, although in recent years they have become more frequent. A typical phenomenon for this area is dry thunderstorms.

The lysimetric station (Figure 1) was equipped in the 1970s by employees of All-Russian Research Institute of Hydraulic Engineering and Land Reclamation, Moscow and Branch at the Solotcha settlement. The lysimetric station includes 16 lysimeters with an area of 1.13 m², evaporators and a tank for water used for irrigating herbs. The layer of disturbed sod-podzolic soil is 1.5 m. The lysimetric station is protected from the unfavorable action of winds from all sides by residential buildings. From an environmental point of view, it is in the zone of maximum emissions of pollutants into the atmosphere.

Fig. 1. Modern view of the station

From 2010 (extremely dry year) to 2015 the weather conditions sharply differed from year to year, which made it possible to more fully assess the results of the studies.

There was used a grass mixture from *Phleumpratense* variety Vologda-Dedinovskaya and *Bromus inermis* variety Dedinovsky – 3. The use of grasses is two-cut, for hay, the seeding rate is at the rate of 5-7 kg/ha.

The experience in studying the use of vermicompost was laid by B.A. Dospekhov method:

- Option 1 – Control – without the introduction of biohumus;
- Option 2 – introduction of 5 t/ha of vermicompost "Biohumus" into the soil (with a

compost moisture content of 8-10%) against the background of mineral fertilizers;
–Option 3 – introduction of 8 t/ha vermicompost "Biohumus" into the soil (with a compost moisture content of 8-10%) against the background of mineral fertilizers;
–Option 4– the introduction of 10 t/ha of dry vermicompost "Biohumus" into the soil (with a compost moisture content of 8-10%) against the background of mineral fertilizers.

Vermicompost, produced by worms at OAO Agrofirma Green-PIK [5, 6, 7, 8], was introduced when sowing grasses in rows at a dose of 5, 8 and 10 t/ha once before the autumn sowing of grasses by hand.

The humus content was determined according to Tyurin. Water-physical and agrochemical studies were carried out according to traditional methods: the density of addition along the genetic horizons was determined by the drilling method, followed by recalculation according to the well-known formula. Soil temperature and moisture were determined by the express method using a tensiometer. Macro-aggregate composition was studied by N.I. Savvinova. The number of aggregates of a certain size was determined according to the guidelines.

The application of mineral fertilizers in the variants of the experiment was N - 90 kgf / ha, P - 60 kgf / ha, K - 90 kgf / ha, which was calculated by the balance method. Mineral fertilizers were applied as follows: ammonium nitrate NH_4NO_3 : double superphosphate $\text{CaH}_2(\text{PO}_4)_2$: potassium chloride KCl : K_2O . When analyzing the content of phosphorus and potassium in fertilizers, we used the express installation "Tefa". The sum of absorbed bases was determined by the Kappen-Gilkovits method, exchange acidity was determined according to Sokolov 1 n. Cl, according to Kappen - hydrolytic acidity, nitrates according to Grandval-Lyazh, the content of mobile phosphorus - according to Truog, 0.002 N. H_2SO_4 , exchange potassium –0.2 N was determined by Brovkina's method. HCl. The agrochemical properties of the sod-podzolic soil were studied according to generally accepted methods in the certified laboratory of All-Russian Research Institute of Hydraulic Engineering and Land Reclamation.

All variants irrigated with a decrease in soil moisture to (PP) were determined manually with a watering can.

Taking into account the deficit of water consumption, the need for irrigation was determined. Moisture reserves at the beginning of the first survey (W_n) were taken equal to the moisture reserves that correspond to the lowest moisture capacity (W_{nw}). The determination of the smallest moisture capacity was carried out after the snow cover and melt water disappeared. The depth of the calculated moisture layer was 30 cm. When the moisture meter reads 109 mm and below, the plants begin experience soil drought and require replenishment of moisture deficit. Estimating soil moisture (W) at the beginning of the calculation period, it was, for example, in 2017 $W_n=136$ mm HB, 109 mm of the pre-irrigation period (PP); in 2019 due to the increase in the power of the sub- and ground biomass $W_H=102$ mm HB, 82 mm PP. The irrigation rate was controlled using a rain gauge. The volume of infiltration water was determined quantitatively by pumping lysimetric water from the pockets of lysimeters. The obtained values were used to calculate water consumption and bioclimatic coefficients of plants.

The counting of the number of microorganisms was carried out by dilution and sowing on nutrient media [3, 4, 5,7]: as simple nutrient media used - mesopatamia broth (MPB), mesopatamia agar (MPA), nutritious gelatin. Complex nutrient media were used as introducing blood, serum, carbohydrates and other substances into simple media. The analysis of the number of spore-forming bacteria was carried out on MPA (meat-peptone agar) and KKA (starch-ammonia agar), on a mixture of equal volumes of MPA and wort agar (MPA+CA–Mishustin's medium), the presence of actinomycetes on CAA, microscopic fungi on CA (wort-agar) after pasteurization of the soil suspension

Czapek'sagar medium was used to obtain pure cultures of microorganisms. The study of catalase activity was carried out according to the method of A.Sh. Galstyan (1987), peroxidase activity was determined by Boyarkin's method. A microbial colony counter was used to count the microorganisms. The physiological state of fungi and actinomycetes in vermicompost was investigated by the method of fouling glasses from Rossi-Kholodny, followed by microscopy at the Department of Agronomy and Agrotechnology of the Russian State Technical University. The application method was used to determine the cellulose-destroying activity of the soil at a depth of 15 cm. The study of the dynamics of the process of decomposition of linen was 1, 2 and 3 months. The intensity of cellulose destruction was determined using the D.G. Zvyagintseva [9]: very weak – up to 10%, weak – 10-30%, medium – 30-50%, strong – 50-80%, very strong – more than 80%. The work provides average data.

Biometric measurements of herbs were carried out according to B.A. Dospekhov method. Crop accounting was determined by mowing grass with a sickle from each meter, followed by drying. Calculation of water consumption (E , m^3/ha) of the studied crops was carried out in accordance with the water balance equation (Kostyakov A.N., 1951). Bioclimatic coefficients (K_b) of agricultural crops were determined by the formula of A.M. and S.M. Alpatyev [10]. The chemical composition and nutritional value of feed – in accordance with GOST; by V.P. Krushchenko (1983) and the nitrogen content was determined using the colorimetric method with Nessler's reagent. The quality studies of perennial grasses were carried out in accordance with the quality standards for hay.

The assessment of the economic efficiency of the action of mineral fertilizers was carried out according to the methodology of the Ryazan State Technical University. The reliability of the research was confirmed by statistical processing of research results using the computer program Statistica 10 [11].

3 Results and discussion

Earlier description of the soil profile [4] showed the average level of fertility of sod-podzolic sandy loam soil with the obligatory application of fertilizers to obtain stable yields of the grass mixture. Agrochemical indicators of biohumus introduced into the soil showed an increase in organic matter in the soil up to 45.2%. The concentration of nitrogen is 3.16%, organic carbon is 3.25%, the C: N ratio is 1.03. The soil temperature during the growing seasons of all years of research contributed to the normal growth and development of grasses and differed from the air temperature by 5-6°C, rainy periods – by 6-10°C.

The conducted microbiological analysis of vermicompost showed that 1 g of dry matter contained up to 11×10^{10} bacteria, 2×10^6 actinomycetes and 9×10^5 fungi. Microscopic examination of fouling glasses made it possible to establish the absence of development of fungal mycelium, and the abundant growth of actinomycetes of the genus *Streptomyces* in the form of microcolonies of various morphology. Sowing bacteria from liquid on agar nutrient media showed that the vermicompost contained a large set of active bacteria: the ammonifying activity in the biohumus sample was 42.4 mg, the nitrifying activity – 17.6 mg. The vermicompost was dominated by fungi of the genus *Trichoderma*. In the studied sample, there were 3-5 thousand/g of representatives of saprophytic microflora – fungi of the genus *Penicilium*, the rest fell on the colonies of the genus *Trichoderma*. [15].

Ammonifiers had a significant effect on the mineralization activity of bacteria. Bacteria developing on MPA were distinguished by high instability in the soil. In the control variant, the number of ammonifiers fluctuated 2300 ... 2750 thousand/g of dry soil, and according to the variants of the experiment, it fluctuated within 4800 ... 5200 thousand/g. When conducting counts and observations, the number of bacteria assimilating

mineral forms of nitrogen (KAA) was counted, in the control variant this indicator reached 3000 ... 3400 thousand/g of dry soil, and with the introduction of vermicompost– this indicator more than doubled and reached 6700 ... 7900 thousand/ha of dry soil.

The study of the presence of the species composition of the bicillarymicropopulation in the sod-podzolic soil during the introduction of vermicompost and irrigation revealed the presence of the *Bacillusmegaterium* species andalso presenceof the *Bacillusmycoides*and*Bacilluscereus*, these microorganisms practically did not assimilate mineral nitrogen, while consuming nitrogen-containing organic matter. The assimilation of complex and poorly available organic substances fell on the share of actinomycetes due to the presence of a powerful proteolytic enzymatic system [12]: the number in the control variant reached 1000 thousand/g of dry soil, and when using biohumus – up to 1300 ... 1400 thousand/g dry soil. The number of microscopic fungi in the soil with the introduction of biohumus increased from 125 to 145 units. The dominant species of microscopic fungi was *Penicillium*.

We have established changes in the agrochemical properties of sod-podzolic sandy loam soil. The control showed a slight decrease of pH_{KCl} to 5,5...5,6, and at the options of the experiment, on the contrary, an increase to 6.1 (when laying the experiment 5.5 ... 5.8), which is most favorable for the development of the main groups of soil microflora.

At the end of the growing season, the sum of exchange bases was assessed, while in the control variant it was 25.6 meq/100 g of soil (the initial value was 21.0 meq/100 g of soil), in all variants of the experiment this indicator significantly increased to 26, 8 meq/100 g of soil. Analyzing the degree of saturation with bases, we found that in all variants of the experiment this indicator decreased, in the control variant it was only 78%, in the variants of the experiment – 69 ... 72%. The nitrogen in the soil was in a mobile and bound form. So, in the control, the nitrogen content decreased, and in the variants of the experiment, it increased. The ammonification process proceeded more successfully than nitrification, therefore, almost 2 times more ammonium forms of nitrogen were found in the soil. In option 4, in comparison with the control, the concentration of nitrate nitrogen increased by an average of 73%, option 2 – by 42% and option 3 – by 14%.

The highest cellulose-degrading activity was noted in option 4 with the introduction of vermicompost 10 t/ha: which amounted to 65% of the decomposition of flaxseed during the growing season, this is about 14% more than in the option with the introduction of vermicompost in the amount of 5 t/ha and 8% more, than on the version with the introduction of vermicompost 8 t/ha. The cellulose-destroying activity on the scale was characterized in the variants as strong, and in the control option – medium.

The pumping of infiltration water before the experiment was carried out in the spring. There was a moisture deficit in the root-inhabited soil layer, as a result of which irrigation was carried out on option 2-9 times; on options 3 and 4-10 times.

Humus formation was calculated using the humification coefficient. The humification coefficient when calculating for perennial grasses was 0.25-0.30. We took in the calculations an average coefficient of 0.27. Analyzing bioguomus, we found that the content of organic matter reached 30%. It was also noted for its highest impact on the soil compared with other test options. We have established an exponential curve, indicating that the dose of vermicompost application in our experiments did not have a significant effect on the amount of humus in the soil. [14].

At the same time, the use of vermicompost in the amount of 10 t/ha in this case is unjustified. In comparison with the control variant, there was a negative balance of organic matter -0.61; with the introduction of vermicompost, the content of organic matter in the soil increased to + 0.12 ... 0.28 t/ha. On option 4 with the introduction of vermicompost with a dose of 10 t/ha, a small amount of organic matter was detected.

In a lysimetric experiment, the toxicological characteristics of the soil were studied. Of the priority microelements for the region Zn, Cu, Cd, Pb, the Zn content in the soil, as the most mobile element, decreased most of all, its amount in all variants of the experiment with the introduction of vermicompost decreased by 2.00 ... 4.25 mg/kg [13]. The content of mobile zinc in all variants of the experiment on different agro background with the introduction of vermicompost was lower than its amount in the control variant by 0.45 mg/kg. The content of mobile Cu decreased by 1.20 mg/kg.

The maximum density of herbage in the first cut was noted in option 4 with the introduction of vermicompost in the amount of 10 t/ha – in comparison with the control by 39%, with the experimental options – by 19 and 2%, respectively. The grass stand was increased in this variant as compared to the control and experimental variants by 118, 50 and 4%, respectively. The highest yield of grasses was established in option 4 with the introduction of vermicompost with a dose of 10 t/ha, in which the mass of grass exceeded the indicator in other options of the experiment by an average of 172, 78 and 15% at HCP05=2.12 t/ha.

Evaluation of the productivity of meadow sown grasses was carried out using statistical processing to confirm reliable, easily comparable data. The data processing on the yield of the rump-timothy grass mixture was carried out using the method. When assessing the rump-timothy grass mixture by yield, the effect of a complex of conditions of the external and internal environment of a particular farm was determined. The yield was calculated using biometric parameters of plant height. When constructing the model, the yield of the rump-timothy grass mixture was based on the following basic data: "X1 – the average amount of precipitation during the growing season, mm, X2 – the amount of precipitation for the year with a temperature above 10°C, mm; X3 is the average annual air temperature, °C; X4 is the sum of active temperatures, °C; X5 – total solar radiation, kcal/cm²; X6 – average annual relative air humidity, %; X7 – biohumus rate, g/m²; X8 – fertilizer dose, g/m²; X9 – average crop yield per 1 lysimeter, kg/m²; X10 – irrigation rate, mm/m²." In the calculations, the yield of products depending on climatic conditions is represented by random values. However, the relationship between X9 and the indicators of natural and climatic conditions is not determined. Using the Kaiser test (according to which, if a factor does not highlight the variance equivalent to the variance of one variable (eigenvalue <1), then it is omitted), the first four factors were selected that explain 79.5% of the total variance. Correlation coefficients of primary signs with the selected factors after rotation of the factor axes by the "varimax" method were obtained from -0.054978 to 0.583585, which made it possible to draw the following conclusions.

The first factor depended on signs X₄, X₈, X₉, X₅. The second factor was highly dependent on signs X₁, X₂. The third factor was highly influenced by signs X₆ and X₇. The fourth factor is closely related to signs X₃ and X₅. Based on the structural accents we established, the interpretation of the factors: F₁ – heat supply coefficient; F₂ – moisture supply coefficient; F₃ – coefficient of favorable growing conditions; F₄ – коэффициент provision of light.

Based on the data obtained, simulators were constructed in the form of histograms of the random variable F1. The system of algorithms for the F1 value is built on the basis of the F1 value histogram. Simulators of other quantities are constructed similarly. Together, all the algorithms formed 20 simulators.

The deviation of the calculated values from the actual obtained values of the yield of the grass mixture was -2.41%.

Thus, the results obtained in the study based on modeling allow us to conclude:

the actual yield of grasses differs from the predicted result by only 2.41-4.0%, that is, the simulative model allows you to accurately calculate the volume of the crop.

The conducted studies of calculations for determining the quality of biomass of forage grasses according to different options confirmed that the hay had a high grade and productivity under irrigation conditions.

The highest concentration of nitrates in the products was established in option 4 with the introduction of vermicompost 10 t/ha (0.09%) and option 3 with the introduction of vermicompost 8 t/ha (0.08%) against the background of mineral fertilizers N90P60K90. The content of nitrates in feed in the control variant was minimal (0.06%), which is explained by the insignificant intake of nitrogen compounds only with atmospheric precipitation. The presence of nitrates in feed differed little according to the variants of the experiment and did not exceed the MPC (0.13%). This dependence is expressed by the formula:

$$N=0.152 + 4.2x + 8.2y \quad (1)$$

We studied the amino acid composition of the feed on option 3 – the introduction of vermicompost 8 t/ha during irrigation: in the first cut, the concentration of essential amino acids lysine, histidine, methionine, tryptophan and others, non-essential – aspartic acid, serine, glutamic acid, proline and others was slightly higher than in the second cut, but within average limits, except for arginine, the concentration of which was higher, on the contrary, in the second cut. Depletion of the grass stand with cystine was noted.

The calculation of the water consumption coefficient showed that in the control it was 0.65 m³ / t, that is, the plants used moisture unproductively, in option 2 – 0.41 m³/t, in option 3 – 0.43 m³/t, option 4 – 0.52 m³/t. To build up their biomass, plants spend almost the same amount of water in options 2 and 3 – 0.41 ... 0.43 m³/t, which is important from an economic point of view. Naturally, the water consumption coefficient depended on the mass of grasses. The calculation of the bioclimatic coefficients of herbs showed that its values change similarly to the indicators of water consumption.

On average, the costs of production of the rump-timothy grass mixture on the variants with the introduction of vermicompost ranged from 3800 to 5100 rubles. on a lysimeter, on control – 3100 rubles. the lowest cost was noted in the variant with the introduction of vermicompost of 8 t/ha and amounted to 2.04 rubles/kg, while the production costs in the control variant were 2.15 rubles/kg of product. With an increase in the application of vermicompost to 10 t/ha, the income of costs decreased. Thus, options 2, 3 and 4 paid for the costs.

4 Conclusions

Research results of vermicompost high number of microorganisms of different groups in it and, accordingly, when introduced into the soil in 1.5 ... 3 times. The content of the main nutrients in the soil increased by 0.2 ... 4 mg/100 g of soil, the cellulose-destroying activity of the soil doubled. The content of organic matter in the soil increased to + 0.12 ... 0.28 t/ha. The plant density increased by 1.5 times, the height – 2 times, the yield of the grass mixture increased on average from 2 to 5 t/ha, the quality of products improved, which corresponded to the zootechnical norm in almost all parameters. The lowest cost was noted in the variant with the introduction of vermicompost at a dose of 8 t/ha and amounted to 2.04 rubles/kg, while the production costs in the control variant were 2.15 rubles/kg of product. With a further increase in the application of doses of vermicompost to 10 t/ha, incomes decreased significantly. So, options 2, 3 and 4 paid for the costs.

Based on the above, it is recommended to add vermicompost to the soil with a dose of 8 t / ha of dry matter (with a moisture content of no more than 8-10%) against the background

of mineral fertilizers and irrigation during the cultivation of rump-timothy grass mixture. In the summer of 2019, the research results passed the first year of approbation at Igor Vyacheslavovich Belousov LLC on an area of 1.5 hectares. The yield was 4.8 t/ha of dry matter, which is 31% higher than the control option – traditional technology.

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