Effect of fertilizers on the accumulation of nutrients by the green mass of the oatmeal mixture in the Vologda Oblast

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Abstract. In the Vologda region over 2016–2018 on average on sod-podzolic medium loamy soil the studies revealed that the calculated doses of fertilizers increase the yield of green mass of the oatmeal mixture by 38–48%, the accumulation of crude protein increases by 315–369 kg/ha, the metabolic energy increases by 26.3–31.8 GJ/ha compared to the reference. In terms of reimbursement, there is an advantage of the organomineral fertilizer system of annual crops over the equivalent mineral fertilizer system by 4.6 kg of green mass and by 12 MJ of metabolic energy per 1 kg of fertilizers.

1. Introduction

By increasing the energy value, it is possible to increase the efficiency of livestock production and its productivity.

In the Vologda Oblast, feeds from perennial legume-cereal grass are widely produced. But annual crops, which in the region are mainly represented by pea and vetch oat mixes, have high nutritional value and are irreplaceable in the biologization of agriculture, are necessary in the structure of sown areas.

When cultivating a waxy mixture, fertilizers are given great importance. Optimum doses of fertilizers significantly increase the yield of green mass and the content of nutrients in it [1, 2, 3].

Therefore, the aim of the research is to study the effect of the minimum and calculated doses of fertilizers on the productivity of the green mass of the oatmeal mixture in the Vologda Oblast.

2. Methods

The studies were carried out in a stationary field experiment in the experimental field of the Vologda State Dairy Academy named after N.V. Vereshchagin from 2016 to 2018 with 4-fold repetition. The area of the plots was 140 m² (14m x 10m), the accounting area was not less than 25 m², the placement of the plots was complex systematic. The soil of the experimental plot was sod-podzolic medium loamy, medium cultivated. The experiment was based on a four-field crop rotation: vetch mix (Nemchinovskaya Yubileinaya spring vetch, Borrus oat), winter rye, potatoes, barley, which was expanded in space and time.

The experimental scheme included variants: reference (without fertilizers) (1 var.), \(N_{12}P_{16}K_{16}\) (2 var.), \(N_{75}P_{35}K_{130}\) (3 var.), \(N_{75}P_{35}K_{160}\) (4 var.), \(N_{50}P_{20}K_{100}\) + aftereffect of 40 t/ha of rotted manure (5 var.).
In the third, fourth, and fifth variants, the doses of fertilizers were calculated using balance coefficients (Kb) for controlling the use of nutrients from fertilizers and soil, as the ratio of the removal of nutrients by the planned crop yield to the dose of fertilizers translated in percent [4, 5]. Fertilizer doses in 3-5 variants were designed to obtain a planned yield of green mass of oatmeal mixture of 25 t/ha.

For research, phosphorus-potassium fertilizers in the form of double superphosphate and potassium salt were manually applied for the main treatment, when sowing, a complex nitrogen-phosphorus-potassium fertilizer was applied, and ammonium nitrate was applied for pre-sowing cultivation.

The yield was taken into account by the continuous method and led to a standard humidity of 75%, the ratio between vetch and oats was established by trial sheaves. The exchange energy content was determined according to GOST R 51038-97, the crude protein content was determined according to GOST 13496.4-93, crude fiber was determined according to GOST 31675-2012, crude ash was determined as per GOST 32933-2014, and fat was determined as per GOST 13496.15-2016.

Mathematical data processing was performed by the analysis of variance [6].

According to the results of previous studies, complete calculated fertilizer systems provide 53% yield of green mass of annual fodder crops significantly (by 11–14 GJ/ha) increase the exchange energy accumulation by the green mass of oatmeal mixture [7]. Fertilizers increase the yield and nutritional value of annual crops [8–14].

3. Results
During the years of research (2016–2018), favorable weather and climatic conditions were established for the growth and development of vetch and oats plants in the mixture, so the planned level of crop productivity was achieved and even exceeded (Figure 1).

In 2016–2018 years of research, the average minimum dose of fertilizers (2 var.) significantly increased the yield of oatmeal mix compared to the control.

Estimated doses of fertilizers (3–5 var.) over 3 years of research on average provided a significant increase in productivity as compared not only to the reference (1 var.), but also to fertilized variant in a dose of N\textsubscript{12}P\textsubscript{16}K\textsubscript{16} (2 var.).

![Figure 1. Productivity of green mass of oatmeal mixture when applying different doses of fertilizers in 2016–2018 (t/ha)](image)

During the years of research, the studied mineral and organomineral fertilizer systems (3–5 var.) differed insignificantly. On average, between 2016 and 2018, the calculated fertilizer systems provided an increase in the yield of green mass of the oatmeal mixture of 8.2–10.4 t/ha (38–48%)
compared with the control. The maximum yield of green mass of oatmeal mixture (31.8 t/ha) was provided by the fertilizer system with a maximum dose of potassium (N\textsubscript{75}P\textsubscript{35}K\textsubscript{160}).

Fertilizers increased the content of certain nutrients in the culture (Figures. 2–6).

![Figure 2. Content of nutrients, % of crude components, 1 variant](image1)

![Figure 3. Content of nutrients, % of crude components, 2 variant](image2)

![Figure 4. Content of nutrients, % of crude components, 3 variant](image3)

![Figure 5. Content of nutrients, % of crude components, 4 variant](image4)

![Figure 6. Content of nutrients % of crude components, 5 variant](image5)

On average, over three years of research, with an increase in the doses of fertilizers applied, there was a tendency toward an increase in the content of crude ash, crude fat, crude fiber, crude protein, and a decrease in the content of nitrogen-free extractive substances.
When applying the calculated doses of fertilizers, the content of f.u. in the green mass of annual crops slightly decreased by 0.02 units compared to the reference. In the studied years, the content of metabolic energy (MA) with the introduction of the minimum dose of fertilizers increased by 0.04 MJ/kg. Although, when using the calculated doses of fertilizers, it decreased by 0.11–0.15 MJ/kg compared to the reference (see Table 1).

**Table 1.** Effect of fertilizers on the nutrient content in the green mass of the oatmeal mixture averaged over the years of research

| Item No. | Variant            | Dry matter [%] | F.u.  | ME [MJ/kg] |
|---------|--------------------|----------------|-------|------------|
| 1       | No fertilizers     | 22.7           | 0.92  | 10.67      |
|         | (reference)        |                |       |            |
| 2       | N12P6K16           | 22.0           | 0.93  | 10.71      |
| 3       | N75P35K130         | 22.3           | 0.90  | 10.56      |
| 4       | N75P35K160         | 22.3           | 0.90  | 10.52      |
| 5       | N50P20K100 + aftereffect of 40 t/ha of rotted manure | 23.0 | 0.90 | 10.56     |

Despite this, the use of calculated doses of fertilizers significantly increased the accumulation of metabolic energy by 26.31–31.80 GJ/ha, feed units by 1.74–1.47 t/ha, crude protein by 315–369 kg/ha compared with control (Figure 7).

**Figure 7.** Accumulation of crude protein, metabolic energy, feed units with a crop of green mass of oatmeal mixture using various doses of fertilizers, on average over the years of research

The reimbursement of fertilizers was determined by adding the green mass of the vetch oat mixture in kilograms per 1 kg of fertilizer active agent. In addition, by an increase in exchange energy, MJ per 1 kg of fertilizer active agent (Figure 8).

Fertilizer reimbursement decreased from 47.7 kg of green mass of oatmeal mixture per 1 kg of fertilizer active agent down to 34.2–38.8 kg with an increase in the applied dose of fertilizers from 44 to 240-270 kg of active agent per ha. In terms of reimbursement, there is an advantage of the organomineral fertilizer system (5 var.) over the equivalent mineral fertilizer system (3 var.) by 4.6 kg. The studied mineral and organomineral fertilizer systems provided a reimbursement of 11.2-15.8 kg higher than the standard mass for annual crops per 1 kg of fertilizer active agent or 1.5-1.7 times (Fig. 8).
Figure 8. Reimbursement of 1 kg of fertilizer active agent by added green mass (kg) and metabolic energy of the oat-oat mixture (MJ), on average over 2016 - 2018.

With an increase in the doses of fertilizers from 44 to 240 and 270 kg a.a/ha, the reimbursement for their metabolic energy decreased by 1.5–1.3 times, from 133 MJ to 88-100 MJ. Assessing the studied design systems of fertilizers, it was found that in terms of the reimbursement of fertilizers considering the exchange energy, organomineral (5 var.) fertilizer has an advantage over the mineral system (3 var.) of 12 MJ.

4. Conclusion

Thus, the estimated doses of fertilizers increase the yield of green mass of the oatmeal mixture by 38–48%, the collection of crude protein by 315–369 kg/ha, f.u. by 1.74–1.47 t/ha, metabolic energy by 26.3–31.8 GJ/ha. In terms of reimbursement, there is an advantage of the organomineral fertilizer system of annual crops over the equivalent mineral fertilizer system by 4.6 kg of green mass and by 12 MJ of metabolic energy per 1 kg of fertilizers.

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