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Energy efficiency of production of Vico-oat mixture at various cultivation technologies

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Abstract. It is well known that growing farm animals requires green food balanced in protein. These requirements are met by the Vico-oat mixture. Green food plays an important role in feeding animals, providing them with essential nutrients and vitamins. Recently, there are more and more questions about environmentally friendly feed production. The selection of technologies for the cultivation of oatmeal mixture for specific farms that use different farming systems and have different material and technical resources is carried out by the Yaroslavl NIIZHK-branch of the Federal research center "V. R. Williams VIC". The article describes the energy efficiency of cultivation of Vico-oat mixture for green mass using extensive, biologized, intensive and high-intensity technologies. The structure of energy consumption in the cultivation of Vico-oat mixture for green mass according to various technologies is given, as well as energy consumption for all products, net energy income, energy cost of dry matter and raw protein.

1. Introduction

Yaroslavl region is a part of the Central Federal district of the Russian Federation and is a system-forming region of the country. The development strategy in the Central district gives priority to the livestock industry. For the sustainable development of this industry, it is necessary to create a solid food base. The intensification of animal husbandry should be accompanied by a faster growth rate in the production of all types of feed, an increase in the proportion of protein components in the feed balance, as well as structural changes in the acreage [1]. According to zootechnical standards, 1 energy feed unit should contain an average of 110 g of raw protein. In fact, the average protein content in the prepared feed is up to 80 g, or 80-85 % of the norm. When there is a protein deficit, there is an overspend of feed per unit of livestock production up to 20-30 %, which is one of the main obstacles to increasing animal productivity. Consequently, for the intensification of animal husbandry, it is assumed that the need for plant protein will increase [2].

The problem of lack of vegetable protein can be solved with the help of legumes. The advantages of legumes over cereals are that they produce more protein per unit area, with better quality and digestibility. Legumes provide the cheapest protein, since they include air nitrogen in the biological cycle, which is not available for other plants. Legumes not only have a high feed value themselves, but



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also when used together with the cereal component, they improve the quality of other low-protein feeds. To obtain a high-protein green mass, annual herbs based on a mixture of vetch and oats are widely used. By regulating the ratio of vetch and oats in the mixture, the feed is balanced in terms of the content of digestible protein. Green mass rich in carbohydrates is given by pure oat crops, but it is poor in protein, and Vika, on the contrary, is rich in protein, but poor in carbohydrates. Therefore, their joint cultivation allows us to obtain the full nutritional value of the food. In addition, the green mass of the mixture contains significantly less fiber than in pure oat crops, which increases the feed's digestibility and protein content. Mixtures give more stable yields, since the decrease in the yield of one crop is compensated by another, and the feed mass is qualitatively improved [3, 4]. In agricultural enterprises, various technologies are used in the cultivation of field crops, the choice of which depends on the system of farming and the availability of the necessary material and technical resources in the enterprise. The technology of growing crops, which is based on the natural fertility of the soil, will be considered extensive. When using mineral fertilizers in optimal or increased doses, as well as chemical plant protection products, intensive technologies are based [5]. On bio-technology of cultivation used minimal doses of mineral fertilizers for the production of environmentally friendly feeds.

For an objective assessment of the cultivation of Vico-oat mixture using various technologies due to systematic changes in prices for materials and services, it is impossible to use conventional calculations of economic efficiency. Therefore, for an objective assessment of various technologies, the method of determining energy efficiency is used. To do this, it is necessary to take into account all energy consumption for cultivation and energy in the crop. If necessary, the energy assessment of cultivation technologies can be translated into any monetary units, that is, their economic assessment is given if the cost of one unit of energy is known [6, 7].

Based on the above, the purpose of our research was to provide an energy justification for various technologies for growing Vico-oat mixture for green fodder in the Central Federal district of the Russian Federation.

2. Methods and materials

The research was conducted in 2019 in a seven-field feed crop rotation on the sowing of a Vico-oat mixture. The soil of the experimental site is sod-podzolic medium loamy with a humus content of 1.87%, P_2O_5 -278 mg / kg of soil, K_2O -128 mg/kg of soil, pH-5.8. The placement of the experiment options is randomized. Experience options: extensive technology without fertilizers; biologized technology-mineral fertilizers $N_{30}P_{30}K_{45}$; intensive technology-mineral fertilizers $N_{60}P_{60}K_{90}$, high-intensity technology-mineral fertilizers $N_{90}P_{90}K_{135}$. The fertilizer was made under preseeding cultivation, in the form of diamphosphoska with the addition of potassium chloride and ammonium nitrate. The research material was spring vetch (*Vicia sativa* L.) Yaroslavskaya 136 and oats (*Avena sativa* L.) Station wagon 1. Seeding rate of the mixture: oats 50% of the total seeding rate (5 million germinating seeds), spring vetch – 50% of the total seeding rate (1.25 million germinating seeds). Sowing was done on April 30, and harvesting was done on June 20.

According to long-term data in the Yaroslavl region, the sum of positive temperatures above 10°C is 1850 °C, the average duration of this period is 125 days. Sum of positive temperatures above 15°C is 1250 °C, the duration of this period is 67 days. Usually May 12 is the date of the last spring freeze. The duration of the frost-free period is about 132 days. In the region there is excessive moisture - the average annual precipitation is 575 mm. The amount of precipitation for a period with a temperature above 10 °C is 250-300 mm, the GTC is 1.4-1.6.

In the year of research, agrometeorological conditions in May and June were favorable for the growth and development of oatmeal mixture. The air temperature in May averaged 14.6°C, which is 3.3°C higher than the long-term average, while the amount of precipitation fell 38 mm, which was 73% of the norm. The June temperature was also 2.4 °C higher than the long-term average and amounted to 18 °C, the amount of precipitation was 54 mm or 79% of the norm. The lack of precipitation in may was compensated by the supply of meltwater in the soil, and in June-by the penetration of the root system of plants into deeper soil horizons.

3. Results and discussion

In the energy assessment of the technology of cultivation of Vico-oat mixture for green feed, a universal energy indicator is used – the ratio of the accumulated energy in the product to the energy spent on its production.

Energy consumption for the formation of agricultural products consists of such indicators as: depreciation and repair deductions for agricultural machinery, energy consumption for seeds, fuel, fertilizers and live labor. To determine the energy consumption, technological maps were compiled for all technologies of cultivation of Vico-oat mixture for green mass. The structure of energy consumption in the cultivation of Vico-oat mixture for green mass according to various technologies is shown in table 1.

Table 1. Structure of energy consumption in the cultivation of Vico-oat mixture for green mass by various technologies, MJ / ha

Indicators	Energy consumption by cultivation technologies							
	extensive		biologized		intense		high intensity	
	MJ/ha	%	MJ/ha	%	MJ/ha	%	MJ/ha	%
Machinery and equipment	94,7	1,2	116,9	0,9	106,3	0,7	109,9	0,6
Seeds	3537,0	45,5	3537,0	28,6	3537,0	23,1	3537,0	18,7
Fertilizers-total	0,0	0,0	3450,0	27,9	6900,0	45,1	10350,0	54,7
including nitrogen	-	-	2400,0	19,4	4800,0	31,4	7200,0	38,0
phosphorous	-	-	600,0	4,9	1200,0	7,8	1800,0	9,5
potassium	-	-	450,0	3,6	900,0	5,9	1350,0	7,1
Combustible	4114,1	53,0	5232,9	42,3	4713,7	30,8	4905,4	25,9
Living labor	23,8	0,3	29,8	0,2	26,9	0,2	28,0	0,1
Subtotal	7769,6	100,0	12366,6	100,0	15283,9	100,0	18930,3	100,0

When cultivating a Vico-oat mixture on a green mass (when converted to dry matter), the highest share in the structure of energy consumption for intensive and high-intensity cultivation technologies is accounted for by fertilizer (45.1-54.7%), for extensive and biologized fuel (53.0-42.3%). Energy consumption for seeds for all cultivation technologies is 3537.0 MJ / ha, but in the structure of energy consumption by technology, its specific weight is distributed from 18.7 to 45.5%, so in extensive cultivation technology it is maximum (45.5%), with intensification its indicators decrease. With the intensification of production, the share of energy consumption for both agricultural machinery and live labor decreases.

Taking into account the energy costs of growing Vico-oat mixture and the energy content of the green mass crop (in terms of dry matter), an energy assessment of various cultivation technologies was carried out. The energy content of the product depends on the yield of the green mass of the Vico-oat mixture and its chemical composition, in particular the content of carbohydrates, protein and fat. When calculating the energy content in the crop, reference data on the energy intensity of organic substances were used [Posypanov 1995]. Net energy income was defined as the difference between the energy content in the dry matter of the green mass and the energy consumption for its cultivation. The energy efficiency coefficient was determined by the ratio of net income to energy consumption. The bioenergetic coefficient (efficiency) of sowing is the ratio of the energy received with the crop to the energy spent on its production. Energy expenditure per unit of yield is the energy cost of production. Indicators of energy efficiency of cultivation of various technologies of cultivation of Vico-oat mixture for green mass are presented in table 2.

Table 2. Energy assessment of the effectiveness of various technologies for the cultivation of Vico-oat mixture

Indicator	Cultivation technology			
	extensive	biologized	intensive	high-intensity
Energy consumed, GJ / ha	7,8	12,4	15,3	18,9
The collection of dry matter, t/ha	5,1	6,1	5,0	5,2
Collection of raw protein, t / ha	0,88	1,00	0,85	0,92
Energy received from production, GJ / ha	59,5	70,7	70,1	58,9
Net energy income, GJ / ha	51,7	58,4	54,8	39,9
Coefficient of energy efficiency of seeding	6,7	4,7	3,6	2,1
Bio-energy factor (efficiency) planting	7,7	5,7	4,6	3,1
Energy cost, GJ / t of dry matter	1,5	2,0	3,1	3,6
Energy cost, GJ / t of raw protein	8,86	12,4	18,0	20,5

As a result of our research, it was found that using extensive technology without the use of fertilizers, the Vico-oat mixture formed a fairly high yield of green mass – 5.1 t / ha of dry matter. This is due to the fact that the soil of the experimental site has a very high availability of mobile phosphorus and increased exchange of potassium (according to Kirsanov), and the low nitrogen content of the soil is replenished by nitrogen fixation in vetches. Legumes under favorable conditions of symbiosis can not only meet their nitrogen needs due to biological nitrogen fixation, but also transfer part of the fixed nitrogen to other crops grown in the mixture, in particular oats [7]. Because of this, extensive cultivation technology expended the lowest amount of energy to produce 7.8 GJ/ha. Extensive cultivation technology resulted in a high net energy yield of 51.7 GJ / ha with a low energy cost of dry matter of 1.5 GJ / t of production, and the coefficients of energy efficiency and bioenergy (efficiency) of sowing are the highest of all the studied cultivation technologies.

Using biologized technology, a low dose of mineral fertilizers $N_{30}P_{30}K_{45}$ was applied to the Vico-oat mixture. Apparently, when the mixture was sown at an early date, the starting dose of mineral fertilizers was effective for both the development of oats and spring vetch. It worked as a supporting fertilizer for oats and spring vetch in the first stages of growth, that is, before the formation of nitrogen-fixing nodules in vetch. On the biologized technology, the yield of the green mass of the mixture reached 6.1 t / ha of dry matter, which is higher than the extensive technology by 18.8%, intensive – by 0.9% and high – intensity-by 20.0%. On bio-technology received the highest energy product of 70.7 GJ/ha, which is above extensive technology 19.6%, intense – 22.0% and high – 17.3%. At the same time, using biologized technology, due to the use of mineral fertilizers, energy consumption for production increases by 1.6 times and reaches 12.4 GJ/ha, and as a result, the energy cost of sowing increases by 33.3%, and the coefficients of energy efficiency and bioenergy (efficiency) of sowing decrease by 42.6% and 35.1%, respectively.

When cultivating a Vico-oat mixture using intensive and high-intensity technologies with the use of increased doses of mineral fertilizers up to $N_{60}P_{60}K_{90}$ and $N_{90}P_{90}K_{135}$, it did not lead to an increase in the yield of dry matter in comparison with extensive technology. But at the same time, there was a significant increase in energy consumption for production by 2.0 and 2.4 times, and the energy cost of sowing increased by 106.7-140.0%.

With the extensive technology of cultivation of Vico-oat mixture for green mass, the collection of raw protein was 0.88 t / ha with an energy cost of 8.86 GJ/t. With the biologized technology of cultivation of Vico-oat mixture for green mass, the protein harvest was 1.00 t / ha, which is 12% more than the collection of raw protein using extensive technology, but its energy cost increased by 40% and amounted to 12.4 GJ/t. When cultivating Vico-oat mixture for green mass using intensive technology, the collection of raw protein decreased by 0.03 t / ha, and its energy cost increased by 2.0 times compared to extensive technology. When cultivating Vico-oat mixture for green mass using high-intensity technology, the collection of raw protein increased by 0.04 t / ha, but its energy cost has already increased by 2.3 times compared to extensive technology.

4. Conclusion

In Yaroslavl region of the Russian Federation on sod-podzolic soil with high availability of phosphorus and high content of exchange potassium because now mixture is economically advantageous to cultivate for extensive and bio-technology.

The use of intensive and high-intensity technology for the cultivation of the mixture on a high agricultural background is less effective. By suppressing symbiotic nitrogen fixation, mineral nitrogen reduces the amount of fixed nitrogen in the air and does not increase the yield of the green mass of the Vico-oat mixture and the collection of raw protein per hectare. Mineral type food videosanal mix – reliable, but expensive method of cultivation.

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