METHODS FOR THE BIOCONVERSION OF MINERAL FERTILIZERS INTO GREEN FODDER ON A PEAT BOG

Tatiana Yuryevna ANISIMOVA

All-Russian Research Institute of Organic Fertilizers and Peat – a branch unit of «Upper Volga Federal Agrarian Research Centre», 2, Pryanisnikov Street, Vyatkino, Sudogda district, Vladimir region, 601390, Russian Federation. Phone: +7 4922 426019, Fax: +7 4922 426010.

Corresponding author: anistan2009@mail.ru

Abstract

The article presents the results of the fifth year of research in a two-factor field experiments, all variants were compared with absolute control without overseeding and fertilizer application. The agroeconomic and agro-energy efficiency of the use of the studied agricultural practices has been determined. An analysis of the agroeconomic and energy assessment showed that the combination of the use of direct sowing and fertilizers over five years of observation and research (from 2017 to 2021) was effective and contributed to a reduction in the cost of 100 feed unit ha-1 by an average of 41-46%; obtaining the greatest profit – 376-826 $ ha-1. The highest payback of a feed unit of 1 kg of NPK was also noted in variants with a cultivated phytocenosis, this indicator increased by 1.2-1.6 times compared to the natural phytocenosis. It was found that the use of overseeding against the background of NPK increased the energy efficiency from 1.6-2.0 to 2.9-3.4. Therefore, taking into account the recoupment of energy costs, we can conclude that N60P90K120 and both doses of NPK in a cultivated phytocenosis can be considered energetically optimal doses of fertilizers in a natural phytocenosis.

Key words: *small-contour developed peat, mineral fertilizer, perennial grasses, sowing without damaging the sod, net income, profitability, agro-energy coefficient*

INTRODUCTION

When solving environmental issues of using and protecting depleted peatlands, the issue of creating cultivated long-term hayfields on peat soils is topical. Perennial grasses are adapted to the conditions of depleted peatlands: they utilize the energy of the sun, atmospheric precipitation, use soil nitrogen more fully, are characterized by longevity and a long growing season, during which they are alienated several times, which determines the characteristics of their mineral nutrition and the need for fertilizers [4, 7, 10, 11].

The use of indicators of agronomic, economic and energy efficiency makes it possible to identify the most profitable options for the use of fertilizer in combination with overseeding and without it, which can be used in agricultural production when growing herbs on a peat bog.

The purpose of the research is to develop effective low-cost agro-biotechnological methods for using the developed small-scale peatland in agricultural production in terms of cost and energy.

MATERIALS AND METHODS

The studies were carried out from 2017 to 2021 in the Vladimir region at the Baigush peat deposit, the type of peat is transitional (A -15.4%, R - 45%). The soil is bog-podzolic (Gleyic (Histic) Albeluvisols) with the following agrochemical indicators: humus content - 1.86 - 2.0%, pHKCl - 6.1-6.4; the content of mobile phosphorus is 56-75 mg/kg of soil, exchangeable potassium is 46.5-58.2 mg/kg, the thickness of the arable layer is 27-39 cm.

On a small part of one of the five peat maps, which was more cultivated and less than the others was in a flooded state, in 2017 a field experiment was laid to determine the effectiveness of using a direct sowing of a mixture of seeds of red clover and timothy meadow in undisturbed sod, and applying various doses mineral fertilizers on the productivity of meadow phytocenosis and soil fertility [1].

The studies were carried out according to the following experience scheme:

1. NF - natural phytocenosis without oversowing clover-timothy mixture - absolute control
2. CF - cultural phytocenosis with overseeding of clover-timothy mixture
3. NF + N60 P60 K90
4. CF + N60 P60 K90
5. NF + N60 P90 K120
6. CF +N60 P90 K120

The plot area is 62.5 m^2 (12.5 × 5 m), 4-fold repetition, the total area under the experiment is 0.15 ha.

Phosphorus, potash and some nitrogen fertilizers were applied during the spring regrowth of grasses. The rest of the nitrogen fertilizers were applied after grass mowing. Research work was based on the methodology for conducting experiments on hayfields and pastures [9]. Soil and plant samples were analyzed in the laboratory using the following methods: pHkcl - according to the TsINAO method (GOST 26483-85); hydrolytic acidity - according to the Kappen method in the modification of TsINAO (GOST 26212-91); the sum of absorbed bases - according to the Kappen method (GOST 27821-88); mobile compounds of phosphorus and potassium - according to the Kirsanov method in the modification of TsINAO (GOST R 54650-2011). The nitrifying capacity of the soil was determined by the Kravkov method, the cellulolytic activity was determined by the application method, and the density and density of the solid phase of the soil was determined by the gravimetric method. Analysis of plant samples was carried out in the laboratory by the following methods: nitrogen content according to GOST R 51417-99 with further conversion into crude protein (coefficient 6.25), phosphorus - according to GOST 26657-97, potassium - according to GOST 30504-97; dry matter content - according to GOST 31640-2012 [12].

Accounting for the yield of grasses was carried out at the onset of the beginning of the phase of flowering of leguminous plants and earing of cereals. Determination of the quality of perennial grasses was carried out using generally established methods [2, 13], calculations of the economic and energy efficiency of agricultural practices were performed using methods for determining the agronomic and economic efficiency of fertilizers in the forage production system [5, 6, 8]. The main indicators of the agronomic efficiency of the studied methods are the yield increase [3]. When calculating the economic and energy efficiency, the costs of seeds, fertilizers, sowing, harvesting and product refinement were taken into account. Energy performance indicators include specific energy consumption of energy per unit of crop and energy return (agro-energy coefficient). Marketable yield was estimated in $ kg-1 in current year prices. For an objective assessment of the studied agricultural practices, they were compared with the basic technology used in areas with thin peat-bog soils, including the following operations: cutting shrubs and small forests with a brush cutter, non-moldboard plowing and harrowing; disking in several tracks; layout; fertilizer application; rolling; sowing; mowing. Doses of fertilizer application, data on the productivity of grasses for the basic technology are taken as in the option "cultivated phytocenosis + N60P90K120".

RESULTS AND DISCUSSIONS

The influence of the studied agricultural practices on the agrochemical characteristics of the soil are presented in table 1. The content of phosphorus and potassium available to plants in the variants with the use of mineral fertilizers increased on average 2-3 times compared to the variants without fertilizers. The increase over five years of research in variants without fertilizers was ~5 mg/kg of mobile phosphorus and ~10 mg/kg of exchangeable potassium. At the same time, in the fertilized variants, the increase relative to the initial content of available phosphorus and potassium was 50-74 mg/kg and 87-118 mg/kg, respectively. The application of the studied methods did not have a negative impact on the pH values in the root layer of the soil of the field experimental plot.

Table 1. Agrochemical characteristics of the soil of the experimental plot (0-20 cm)

Options	pH		Mobile Phosphorus content, mg kg^{-1}		Exchangeable Potassium content, mg kg^{-1}	
	1*	2*	1*	2*	1*	2*
NF- natural phytocenosis	6.2	6.15	51.7	55.5	40.8	50.4
CF- cultural phytocenosis	6.05	6.35	48.4	52.1	32.1	56.8
NF+N60P60K90	6.2	6.64	51.7	102	40.8	146
CF+ N60P60K90	6.05	6.06	48.4	126	32.1	150
NF+ N60P90K120	6.2	6.29	51.7	110	40.8	128
CF+ N60P90K120	6.05	6.14	48.4	102	32.1	123

Note: 1* - before laying the experience, 2* - at the end of the fifth year of research
Source: Own calculation.

Thus, it can be concluded that the use of mineral fertilizers contributed to the accumulation of reserves of mobile phosphorus and potassium compounds in the arable soil layer, which reduced the risk of soil degradation in the developed peat bog. The application of the studied agricultural practices had an impact on the yield of green mass of the herbage. For four years of economic use of grasses, their yield of grasses against the background of mineral fertilizers in combination with oversowing significantly exceeded the control variant, as well as the variant with oversowing without fertilizers (Table 2).

Table 2. Productivity of green mass of perennial grasses for four years of economic use, t ha-1

Options	Years of use				Average	Collection on average for four years	
	2018	2019	2020	2021		f.u.*	d.p.*
Natural phytocenosis							
Without fertilizer (control)	0.34	0.65	7.8	2.4	2.8	0.56	0.18
N60H60K90	0.86	2.53	16.4	7.4	6.8	1.36	0.28
N60P90K120	1.0	3.85	21.9	8.0	8.7	1.73	0.36
Cultural phytocenosis							
Without fertilizer	1.92	2.3	14.2	4.5	5.7	1.14	0.24
N60H60K90	2.46	5.01	27.6	13.5	12.1	2.43	0.51
N60P90K120	2.34	6.12	28.6	15.0	12.9	2.58	0.55
$LSD^*_{0.5}$	0.4	1.3	2.7	3.0			
$LSD_{0.5}$ factor A	0.1	0.8	1.9	2.2.			
$LSD_{0.5}$ factor B	0.3	0.9	1.6	1.8			

*Note: f.u. – feed unit; d.p. – digestible protein; LSD - least significant difference; factor A – overseeding; factor B - fertilizer application
Source: Own calculation.

The highest productivity of grasses was noted with the combined use of agricultural practices and, on average, exceeded the control by 4.3-4.8 times, the use of only overseeding allowed to increase the productivity of grasses by 2 times, and the use of only fertilizers without overseeding - on average 2.8-3 times. The use of overseeding and the annual application of mineral fertilizers had a positive effect on the nutritional value of grasses: the content of feed units and digestible protein in grass yields per 1 ha. A similar trend in the influence of agricultural practices in the cultivation of clover-timothy mixture was also noted when calculating the content digestible protein in the resulting green fodder. An assessment of the agroeconomic efficiency of the studied agricultural practices over a five-year period is presented in Table 3. The combination of fertilizers with overseeding provided the highest net income (376-826 $ ha-1) and profitability (72.2-85.5%), the indicator the payback of a feed unit of 1 kg of NPK increased by 1.2-1.6 times compared with the options with natural phytocenosis.

Table 3. Agro-economic efficiency of using direct sowing and application of fertilizers on an exhausted peatland when growing perennial grasses (five years in total)

Options	**Collections feed units, T ha^{-1}**	**Conditionally net income, \$ ha^{-1}**	**Profitability, %**	**Payback, f.u./1 kg NPK**
Natural phytocenosis				
Without fertilizer (control)	2.23	-	-	-
N60H60K90	5.44	77.8	8.4	3.1
N60P90K120	6.94	210	19.8	3.5
Cultural phytocenosis				
Without fertilizer	4.58	376	79.8	-
N60H60K90	9.71	826	85.5	4.9(7.1)*
N60P90K120	10.4	803	72.2	4.3(6)*
Basic technology				
N60P90K120	10.4	561	41.4	3.1

Note: * to control.
Source: Own calculation.

The energy assessment of the studied agrobiotechnologies was carried out taking into account four main indicators: the collection of metabolizable energy from 1 ha, their payback from the collection of metabolizable energy - the agro-energy coefficient (energy return) and the unit costs per 1 Giga Joule (GJ) produced. Such an analysis makes it possible to justify multivariate proposals, taking into account the need to increase feed production and the possibility of applying various costs for this (Table 4).

Table 4. Agro-energy efficiency of the use of agricultural practices in the cultivation of perennial grasses

Options	**Output from 1 ha**		**Total energy costs**		**Energy return, units**
	DM, t	EE, GJ	Per 1 ha GJ	Per 1 kg DM, MJ	
Natural phytocenosis					
Without fertilizer (control)	4.0	47.1	11.6	2.9	4.0
N60H60K90	7.9	61.1	38.6	4.9	1.6
N60P90K120	10.8	83.5	41.0	3.8	2.0
Cultural phytocenosis					
Without fertilizer	10.0	69.4	12.5	1.2	5.5
N60H60K90	13.9	115	36.3	2.8	2.9
N60P90K120	16.9	144	41.8	2.6	3.4
Basic technology					
N60P90K120	16.9	144	91.8	5.4	1.6

*Note: DM- dry matter; EE - exchange energy
Source: Own calculation.

The lowest costs of total energy per 1 ha were obtained in the variants without the use of mineral fertilizers and they amounted to 11.6-12.5 GJ, per 1 kg of dry matter - 1.2-2.9 MJ, and the highest agro-energy coefficient was noted, which amounted to 4.0-5.5 units. But this does not mean that options without fertilizers are promising, because. nutrient reserves in the soil of these options are not replenished and there is a risk of degradation of soil fertility. It has been established that N60P90K120 and both doses of NPK in a cultivated phytocenosis can be considered energetically optimal doses of fertilizers in a natural phytocenosis, the energy return in these options was 2.0-3.4 units.

CONCLUSIONS

Profit and the greatest payback of 1 feed unit in the experiment depended on the use of fertilizers and the use of overseeding of grass seeds. An analysis of the agro-economic and energy assessment showed that the combination of the use of methods for five years of research was effective and contributed to a reduction in the cost of 100 f.u. ha-1 by an average of 41-46%; getting the most profit.

Thus, the collection of fodder units per 1 ha with the use of only oversowing increased 2 times, and with a combination of fertilizers with oversowing, compared with options without oversowing, 1.5-1.8 times, while compared with the control - 4.4 times. -4.7 times. The highest payback of a feed unit of 1 kg of NPK was also noted in variants with a cultivated phytocenosis, this indicator increased by 1.2-1.6 times compared to the natural phytocenosis. It was found that the use of overseeding against the background of NPK increased the energy efficiency from 1.6-2.0 to 2.9-3.4.

Therefore, taking into account the payback of energy costs and the impact of methods on soil fertility, we can conclude that N60P90K120 and both doses of NPK in a cultivated phytocenosis can be considered energetically optimal doses of fertilizers in a natural phytocenosis.

REFERENCES

[1]Anisimova, T. Yu., 2022, Results of the application of direct sowing and fertilizers in growing permanent grasses on worked-out peatland, Evolution and degradation of the soil cover, pp. 266-268.

[2]Gusakov, V. G., Brechko, Ya. N., Sumonov, M. E., 2006, Reference book of labor and material costs for agricultural production, Minsk, Belarusian Science, 709 p.

[3]Kosenko T. G., 2014, Evaluation of the ecological and economic efficiency of agricultural production, Bulletin of the Don State Agrarian University,№. 4-3, pp. 12-17.

[4]Kovshova, V. N., 2020, The role of permanent grasses in the development of exhausted peat soils in the Volga-Vyatka economic region, Multifunctional adaptive fodder production, pp. 30-38.

[5]Kutuzova, A.A., 2019, Economic efficiency of systems and perfect technologies for the production of voluminous feed on hayfields, Achievements of science and technology of the agro-industrial complex, Vol.33 (6), 44-50.

[6]Lazarev, N. N., 2005, Agro-energy efficiency of improving natural and old-sown hayfields and pastures, Izvestia of the Timiryazev Agricultural Academy, № 4, pp. 60-67.

[7]Meerovsky, A.S., Pastushok, R.T., Biryukovich, A.L., Mikhailova, O.S., 2021, Technological regulations for the production of green fodder and raw materials for forage harvesting on improved hayfields, Reclamation. №. 1 (95), pp. 31-37.

[8]Mikhailichenko, B.P., Kutuzova, A.A., Novoselov Yu.K. et al., 1995, Methodological manual for agro-energy and economic assessment of technologies and systems of fodder production, Moscow, Rosselkhozakademiya, 174 p.

[9]Novoselov, Yu.K., Kireev, V.N. et al, 1987, Guidelines for conducting field experiments with fodder crops, 2nd ed., M.: Williams's Feed Research Institute, 197 p.

[10]Petermann, J. S., Buzhdygan, O. Y. Grassland biodiversity, 2021, Current Biology, T. 31, №. 19, pp. R1195-R1201.

[11]Plantureux S., Peeters A., McCracken D., 2005, Biodiversity in intensive grasslands: Effect of management, improvement and challenges, Agronomy research, T. 3, №. 2, pp. 153-164.

[12]Sheudzhen, A. Kh., Bondarev,a T. N., 2005, Methods of agrochemical research and statistical evaluation of their results, Maykop: JSC "Polygraph-South, 659 p.

[13]Sychev, V.G., Lepeshkin, V.V., 2002, Guidelines for assessing the quality and nutritional value of feed, Moscow: Ministry of Agriculture of the Russian Federation, TsINAO, 75 p.