https://doi.org/10.26898/0370-8799-2021-6-5
УДК: 631.8
Тип статьи: оригинальная
Type of article: original

ПРОДУКТИВНОСТЬ ЕСТЕСТВЕННЫХ ФИТОЦЕНОЗОВ НАМСКОГО АГРОЛАНДШАФТА ЯКУТИИ ПРИ ОРГАНИЧЕСКОМ И МИНЕРАЛЬНОМ РЕЖИМАХ ПИТАНИЯ

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Представлены результаты изучения потенциала продуктивности естественных фитоценозов разного видового состава Намского агроландшафта среднетаежной подзоны Республики Саха (Якутия). Исследования проведены в 2009–2016 гг. Почвы опытного участка мерзлотные с маломощным гумусовым слоем. Изучено влияние минеральных и органических удобрений на продуктивность остепненных лугов. На разнотравно-злаковом, пырейном, остепненном фитоценозах использовали следующие приемы по органоминеральному питанию растений: контроль (без удобрения); перегной 20 т/га; перегной 20 т/га 1 раз в 4 года + $N_{60}P_{60}K_{60}$ ежегодно; $N_{30}P_{30}K_{30}$ ежегодно; перегной 20 т/га ежегодно. Установлены оптимальные нормы внесения органических и минеральных элементов питания для улучшения потенциала продуктивности естественных остепненных лугов. Наиболее высокий потенциал продуктивности в условиях Намского агроландшафта получен при совместном применении органических и минеральных удобрений (перегной 20 т/га 1 раз в 4 года + $N_{60}P_{60}K_{60}$ ежегодно). На разнотравно-злаковом и пырейном фитоценозах урожайность сена достигала 23,0–24,1 ц/га. Сбор с 1 га обменной энергии составил 27,0–22,4 ГДж, кормовых единиц – 1472–1663, сырого протеина – 336–371 кг. Содержание переваримого протеина в 1 к. ед. у разнотравно-злакового равнялось 92 г, пырейного – 102 г. Ежегодное внесение минеральных удобрений в дозе 60 кг/га действующего вещества обеспечивало повышение урожайности естественных фитоценозов в 2 раза в зависимости от агроклиматических условий вегетационного периода. Влияние минеральных удобрений и совместного внесения их с органическими на урожайность естественных фитоценозов статистически достоверно, что свидетельствует о возможности регулирования продуктивности остепненных фитоценозов.

Ключевые слова: органические и минеральные удобрения, естественный фитоценоз, пырейный, разнотравно-злаковый, остепненный агроландшафт

PRODUCTIVITY OF NATURAL PHYTOCENOSES OF THE NAMSKY AGROLANDSCAPE IN YAKUTIA UNDER ORGANIC AND MINERAL NUTRITION REGIMES

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The results of the study of the productivity potential of natural phytocenoses of different species composition in the Namsky agrolandscape of the middle taiga subzone of the Republic of Sakha (Yakutia) are presented. The research was conducted in 2009-2016. The soils of the experimental plot are permafrost soils with a thin humus layer. The effect of mineral and organic fertilizers on the productivity of steppe meadows was studied. On herb-grass, wheatgrass, steppificated phytocenoses the following practices of organo-mineral nutrition of plants were used: control (no fertilizer); humus 20 t/ha; humus 20 t/ha once every 4 years + $N_{60}P_{60}K_{60}$ annually; $N_{30}P_{30}K_{30}$ annually; humus 20 t/ha annually. The optimum rates of organic and mineral nutrients to improve the productivity potential of natural steppe meadows have been established. The highest productivity potential in the Namsky agrolandscape was obtained with the combined application of organic and mineral fertilizers (humus 20 t/ha once every 4 years + $N_{60}P_{60}K_{60}$ annually). On herb-grass and wheatgrass phytocenoses hay yield reached 23.0-24.1 c/ha. Yield per 1 ha of metabolizable energy was 27.0-22.4 GJ, fodder units 1472-1663, crude protein 336-371 kg. The content of digestible protein in 1 fodder unit in herb-grass was 92 g, in wheatgrass - 102 g. The annual application of mineral fertilizers at a dose of 60 kg/ha of the active substance provided a 2-fold increase in the productivity of natural phytocenoses, depending on agroclimatic conditions of the growing season. The influence of mineral fertilizers and their joint application with organic fertilizers on the yield of natural phytocenoses is statistically reliable, which indicates the possibility of regulating the productivity of steppificated phytocenoses.

Keywords: organic and mineral fertilisers, natural phytocenosis, wheatgrass, herb-grass, steppificated agrolandscape

Для цитирования: *Устинова В.В., Барашкова Н.В.* Продуктивность естественных фитоценозов Намского агроландшафта Якутии при органическом и минеральном режимах питания // Сибирский вестник сельскохозяйственной науки. 2021. Т. 51. № 6. С. 39–46. https://doi.org/10.26898/0370-8799-2021-6-5

For citation: Ustinova V.V., Barashkova N.V. Productivity of natural phytocenoses of the Namsky agrolandscape in Yakutia under organic and mineral nutrition regimes. *Sibirskii vestnik sel'skokhozyaistvennoi nauki = Siberian Herald of Agricultural* Science, 2021, vol. 51, no. 6, pp. 39–46. https://doi.org/10.26898/0370-8799-2021-6-5

Конфликт интересов
Авторы заявляют об отсутствии конфликта интересов.
Conflict of interest
The authors declare no conflict of interest.

INTRODUCTION

Improvement of natural forage lands is an important problem of grassland fodder production in the Republic of Sakha (Yakutia). Due to the high cost and complicated logistics of delivering mineral fertilizers, many farms cannot use them. The productivity of natural grasslands depends to a large extent on the climatic conditions of the growing season. To avoid dependence of the yield and productivity of natural grasslands on weather conditions, the use of organic fertilizers is relevant.

Under the conditions of the Namsky agrolandscape on permafrost meadow-chernozem soils, natural meadow steppes respond differently to the nutritional regime. The nutrient supply of meadow plants significantly affects the species composition, economic yield and productivity potential of the natural phytocenoses.

The purpose of the study is to study the effect of mineral and organic fertilizers on the productivity of steppe meadows in the conditions of the Namsky agro-landscape of Yakutia.

The objective of the study is to establish optimal rates of organic and mineral nutrients to improve the productivity potential of natural steppe meadows.

MATERIAL AND METHODS

In the field experiment using the factorial scheme the effectiveness of the influence of or-

ganic and mineral fertilizers in a wide range of doses and combinations on the productivity of phytocenoses was studied. As a result of comprehensive research, new data on the effect of the most important fertilizer systems: mineral, organic and organomineral - on soil fertility and its biological activity were obtained.

The objects of the research were different steppe communities: motley grass-grasses, wheatgrass, and steppe phytocenoses under different feeding regimes under conditions of natural moisture. The studies of the baseline project 2009-2016 were conducted in steppe meadows at the Markhinsky station of the Institute of Biological Problems of the Cryolithozone of the Siberian Branch of the Russian Academy of Sciences. The station is located 13 km from Yakutsk; according to the agrolandscape zoning of the middle taiga subzone of Yakutia, it is located in the Namsky agrolandscape and occupies the sixth agroecological land group. The area of the Namsky agrolandscape is 2,575 thousand ha, or 6.0% of the Lena-Vilyui interfluve [1]. This agro-landscape is an erosion-accumulative gentle-wave plain with absolute altitudes of 300-400 m, formed by Neogene-Quaternary deposits with permafrost taiga paleo- and medium-salty, medium-loam soils, which are covered by larch-motley grass-grasses and lingonberry forests.

The climate of the Namsky agricultural landscape is moderately cold and arid. January air temperature is -41.2 °C, July temperature rises to 17.6 °C. The annual amount of precipitation is 264 mm, of which 123 mm falls during the active vegetation period. The average duration of the frost-free period is 79 days; it varies considerably depending on the location. The soil is suitable for agricultural work from May 17-19. The sum of average daily air temperatures above 10 °C is 1414-1642 °C. Moisture coefficient for the year is 0.90, during the active vegetation period of plants - 0.49, i.e. moisture content of the territory is deficient and acutely deficient [2].

The sixth agro-ecological group of lands of the Namsky agro-landscape is represented by saline lands of the Lena River floodplain terraces and occupies an area of 0.15 thousand m2 [3]. The dominant soils are permafrost meadow-chernozem solonetzic soils. The soils under steppe meadows are characterized by high dryness and relatively intensive heating of the root zone. The upper horizons of these soils are acidified, only in the lower strata alkalinization is noted, the pH of aqueous suspension reaches 7.4. The spring humidity of permafrost sod soil is characterized as insufficient for the initial vegetation of meadow grasses, so steppe meadows are characterized by low biological productivity.

The soils of the study area at the “Marikhinsky” station are permafrost floodplain meadow-chernozem soils. The content of humus in the 0-20 cm arable layer is 2.5%, mobile phosphorus is 279 mg/kg of soil, and exchangeable potassium is 104 mg/kg [4]. The weather conditions of the vegetation periods 2009-2016 differed from each other and included all the features of agroclimatic conditions of the Middle Lena valley. The amount of precipitation of 161-170 mm is considered optimal for growth and development of perennial grasses in the conditions of the Namsky agrolandscape during the growing season. The driest and hottest growing season was 2015 (HTC 0.50) with 121 mm of precipitation while the norm was 161 mm. The wettest period was 2013 (HTC 0.90). Heavy rains occurred in spring and in the first half of summer, and the amount of precipitation during the growing season reached 234 mm. The year 2014 was variable-humidity year (HTC 0.70) with dry spring and rainy summer. 2016 was the most favorable by temperature regime and the amount of precipitation (HTC 0.80).

Different in temperature and precipitation weather conditions of 2009-2016 influenced the growth and development of plants, the passage of phenological phases, the formation of yield and development of the root system of steppe plants in the station "Marikhinsky" [5].

Motley grass-grasses, wheatgrass, and steppe phytocenoses used the following methods for organomineral nutrition of plants: control (no fertilizer); humus 20 t/ha; humus 20 t/ha once every 4 years + $N_{60}P_{60}K_{60}$ annually; $N_{30}P_{30}K_{30}$ annually; humus 20 t/ha annually.

The studies used generally accepted methods for meadow science and grassland management. All records and observations were made according to the methods [1,2], statistical processing of yield data was carried out by the method of variance analysis according to B.A. Dospekhov[3]. The chemical composition of hay forage (crude fiber, fat, crude ash, nitrogen, phosphorus, calcium) was determined in the biochemistry laboratory of the Yakutsk Research Institute of Agriculture. Energy fluxes in meadow phytocenoses were evaluated according to the method[4].

RESULTS AND DISCUSSION

For the first time under the conditions of the Namsky agricultural landscape on permafrost meadow-chernozem soils, the productivity potential of meadow steppes with different species composition was evaluated.

According to the VNIIK methodology, the productivity potential of meadow ecosystems is determined by the collection of metabolizable energy, fodder units and crude protein from 1 hectare. It is established in our studies that the productivity potential of meadow steppes depending on fertilizers is conditioned by weather conditions of vegetation periods, biological features of meadow plants and nutrition regime.

In the conditions of the Namsky agrolandscape, a natural herb-grass phytocenosis without fertilization with the content of cereals in the herbage up to 65.2% ensured the productivity from 1 ha in terms of the collection of exchange energy up to 8.8 GJ, fodder units - 595, crude protein - 99 kg. The content of digestible protein in 1 fodder unit was 53 g, which is 1.9 times lower than the zootechnical norm (see Table 1).

Under the conditions of motley grass-grasses phytocenosis the joint use of organic and mineral fertilizers (humus 20 t/ha once in 4 years + N60P60K60 annually) ensured the increase of productivity by 2.2 times with the yield of 23.0 c/ha of hay of 1st class with raw protein content up to 14.6%. The optimum yield of 27 GJ of metabolizable energy, 1472 fodder units, and 336 kg of crude protein per 1 ha was formed. At the same time, the content of digestible protein in 1 fodder unit in herb-grass meadow reached 92 g when the norm was 105 g.

Under this nutritional regime, the dominance of cereal species (Elytrígia répens, Koeleria pyramidata (Lam.) P. Beauv., Poa stepposa (Kryl.) Roshev.) in motley grass-grasses phytocenosis was noted. The content of wild cereals was up to 93.1%, herbs - up to 6.9% of DM, indicating the responsiveness of cereal species to nitrogen fertilizers.

The annual application of mineral fertilizers at a dose of $N_{60}P_{60}K_{60}$ in motley grass-grasses phytocenosis with the content of wild grains up to 87.0% ensured productivity per 1 ha in terms of metabolizable energy harvesting 18.8 GJ, fodder units - 1327, crude protein - 278 kg. According to the content of digestible protein in 1 k. unit. (79 g) the herb-grass phytocenosis did not meet the zootechnical standards [6].

When mulch 20 t/ha was applied once in 4 years + 20 t/ha annually, motley grass-grasses phytocenosis with cereals 66,2-86,4% CB ensured productivity per ha in terms of metabolizable energy collection 12,5-12,5 GJ, fodder units - 847-725, crude protein - 153-154 kg.

A natural wheatgrass phytocenosis without fertilizers containing 87.5% CB in the grass of wheatgrass (Elytrigia repens) had an average productivity of 13.5 GJ, fodder units - up to 927, crude protein - 179 kg from 1 ha of harvested metabolizable energy. At the same time the provision of 1 fodder unit (66 g) of digestible protein. (66 g) of digestible protein was insufficient. The mineral dietary regime of wheatgrass phytocenosis at the dose of $N_{60}P_{60}K_{60}$ annually resulted in increased productivity per hectare in raw protein collection - 403 kg and high provision of 1 k. unit of digestible protein - 105 г.

[1]Methodology of experiments in hayfields and pastures. M., 1971. P. 1. 229 p.

[2]Methodology of experiments in hayfields and pastures. M., 1971. P. 2. 174 p.

[3]Dospekhov B.A. Methodology of field experience. Moscow: Agropromizdat, 1985. 375 p.

[4]Methodological Guide for the Assessment of Energy Flows in Meadow Agroecosystems. Moscow: VNIIK named after V.R. Williams, 2007.

Табл. 1. Потенциал продуктивности естественных фитоценозов разного состава при органоминеральном режиме питания (среднее за 2009–2016 гг.)
Table 1. Productivity potential of natural phytocenoses of different composition under organo-mineral nutritional regime (average for 2009–2016)

Dietary pattern	Content of wild species, %			Yield, c/ha DM	Production per 1 ha			Content of digestible protein in 1 f.u., g
	Cereals	Legumes	Forbs		exchange energy, GJ/ha	f. u.	crude protein, kg	
Motley grass-grasses phytocenosis								
Control (without fertilizer)	65,2	15,2	19,7	10,1	8,8	595	99	53
Mould 20 t/ha once every 4 years	66,2	20,1	13,7	14,6	12,5	847	153	55
Mould 20 t/ha once every 4 years + $N_{60}P_{60}K_{60}$ annually	93,1	–	6,9	23,0	27,0	1472	336	92
$N_{60}P_{60}K_{60}$ annually	87,0	0,8	10,8	21,4	18,8	1327	278	79
$N_{30}P_{30}K_{30}$ annually	82,1	0,9	17,1	15,7	13,9	973	179	67
Mould 20 t/ha annually	86,4	1,1	12,6	14,5	12,5	725	154	69
LSD_{05}				3,4				
Agropyron phytocenosis								
Control (without fertilizer)	87,5	3,9	8,6	15,2	13,5	927	179	66
Mould 20 t/ha once every 4 years	90,5	2,3	7,3	16,7	14,7	1052	225	81
Mould 20 t/ha once every 4 years + N60P60K60 annually	92,0	0,8	7,2	24,1	22,4	1663	371	102
$N_{60}P_{60}K_{60}$ annually	93,2	0,6	6,3	20,0	18,2	1360	403	105
$N_{30}P_{30}K_{30}$ annually	90,4	0,0	9,7	17,3	15,5	1124	263	93
Mould 20 t/ha annually	85,0	3,2	11,9	15,7	14,6	958	195	67
LSD_{05}				4,0				
Steppificated phytocenosis								
Control (without fertilizer)	19,8	13,1	67,1	7,0	6,0	420	58	39
Mould 20 t/ha once every 4 years	36,8	18,1	45,2	9,0	8,0	567	76	46
Mould 20 t/ha once every 4 years + N60P60K60 annually	45,6	0,4	54,1	17,1	16,0	1197	214	82
$N_{60}P_{60}K_{60}$ annually	45,5	1,4	53,2	14,7	13,0	911	157	64
$N_{30}P_{30}K_{30}$ annually	31,5	1,5	67,1	13,1	11,4	799	139	65
Mould 20 t/ha annually	47,0	9,3	43,8	12,6	10,8	668	94	45
LSD_{05}				3,3				

The natural steppe phytocenosis without fertilizers with herbs and cereals up to 67.1 and 19.8% DM, respectively, had the lowest productivity potential with an average yield of 7.0 c/ha DM. The content of digestible protein in 1 f.u. was 39 g, which is significantly lower than the zootechnical norm. Productivity of the phytocenosis without fertilizers in terms of metabolizable energy collection was 6.0 MJ/ha, fodder units - 420, crude protein - 58 kg/ha.

With a combination of organic and mineral fertilizers (mulch 20 t/ha 1 time in 4 years + $N_{60}P_{60}K_{60}$ annually) the productivity potential of this phytocenosis increased: the collection of metabolic energy to 16.0 GJ, fodder units - to 1197, crude protein - to 214 kg/ha. The content of digestible protein in 1 fodder unit increased to 82 g, which is lower than the zootechnical norm.

A combined application of organic and mineral fertilizers (mulch 20 t/ha once in 4 years + $N_{60}P_{60}K_{60}$ annually) proved to be most effective in the meadow steppes of the Namsky agrolandscape, which led to a 2-fold increase in the yield with good quality hay forage. The exchange energy per 1 ha was 27.0-22.4 GJ, fodder units 1472-1663, crude protein 336-371 kg. By the content of digestible protein in 1 fodder unit herb-grass and wheat grass phytocenosis with the content of cereals from 88 to 93% corresponded to zootechnical norms (93-105 g). On these phytocenoses the 1st class hay yield reached 23.0-24.1 c/ha. The content of digestible protein in 1 cfu was 92 g in motley grass-grasses phytocenosis, 102 g in wheat grass phytocenosis, 82 g in steppe grass phytocenosis.

It is important to note the effectiveness of annual application of mineral fertilizers at a dose of 60 kg/ha, which provides an increase in the yield of natural phytocenoses by about 2 times [7-9]. At the same time, a significant variation of economic yield of phytocenoses by years of research was noted. This pattern was particularly evident in the wheatgrass phytocenosis. The most effective was the joint application of organic and mineral fertilizers (mulch 20 t/ha once in 4 years + $N_{60}P_{60}K_{60}$ annually), which provided a hay yield of wheatgrass phytocenosis up to 24.1 c/ha.

Long-term results of our experiments indicate that in the conditions of the sixth agroecological group of lands of the Namsky agrolandscape the most effective is the joint application of organic and mineral fertilizers (mulch 20 t/ha once in 4 years + $N_{60}P_{60}K_{60}$ annually). This application formed the maximum yield of herb-grass, wheatgrass and steppe phytocenoses regardless of the species composition and the degree of moisture of the growing season. On average for the years of research the combined application of organic and mineral fertilizers provided the yield of motley grass-grasses phytocenosis 23.0 c/ha, wheatgrasses - 24.1, steppe - 17.1 c/ha (see Table 2).

Табл. 2. Урожайность естественных фитоценозов при внесении удобрений (среднее за 8 лет), ц/га
Table 2. Productivity of natural phytocenoses with fertilization (average over 8 years), c / ha

Experiment variant	Phytocenosis		
	steppificated	motley grass-grasses	agropyron
Control (without fertilizer)	6,9	10,1	15,1
Mould 20 t/ha once every 4 years	9,4	14,6	16,7
Mould 20 t/ha once every 4 years + N60P60K60 annually	17,0	23,0	24,1
$N_{60}P_{60}K_{60}$ annually	14,6	21,4	20,0
$N_{30}P_{30}K_{30}$ annually	12,6	15,7	17,3
Mould 20 t/ha annually	12,2	14,5	15,7
Confidence interval	1,7	3	4,4
Proportion of the influence of the factor "Year" *	8	21	55
Proportion of the influence of the factor "Fertilizer"	21	21	9

*Процент от общей вариации признака.

CONCLUSION

In the Namsky agro-landscape, the highest productivity potential was obtained with the combined application of organic and mineral fertilizers (mulch 20 t/ha once in 4 years + N60P60K60 annually). On motley grass-grasses and wheatgrass phytocenoses hay yield reached 23,0-24,1 c/ha with exchange energy 27,0-22,4 GJ, fodder units 1472-1663, crude protein 336-371 kg per 1 ha. The content of digestible protein in 1 fodder unit of motley grass-grasses phytocenosis was 92 g, that of wheat grass - 102 g. The influence of mineral fertilizers and their coapplication with organic fertilizers on the productivity of natural phytocenoses is statistically reliable, which indicates the possibility of regulating the productivity of steppe phytocenoses. Meanwhile, the efficiency of mineral fertilizers and their coapplication with organic fertilizers significantly depended on the weather conditions of the growing season, which was most clearly manifested in the couch grass phytocenosis. At the same time on low-productive steppe phytocenoses with insufficient moisture application of organic and combined organic and mineral fertilizers positively affects the yield of fodder mass.

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Дата поступления статьи / Received by the editors 31.07.2021
Дата принятия к публикации / Accepted for publication 25.11.2021
Дата публикации / Published 27.12.2021