The role of mineral fertilizers in the creation of pasture agrophytocenoses

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Abstract. The scientific paper presents the results of research for 2023, carried out at the experimental field of North-West Research Institute of Dairy and Grassland Economy in the Vologda region, on the influence of mineral fertilizers on the productivity and nutritional value of perennial cereals and legume-cereal grass mixtures. During the research, a noticeable effect of the nitrogen dose on the yield of the dry mass of the grass mixture was established. With an increase in the dose of nitrogen application by 30 kg a.d., the yield increase may average 0.408 tons. In total, during the season on herbage with the use of fertilizers, productivity amounted to 9.16-10.27 tons of dry weight, crude fat content 0.28-0.31 tons, crude protein 1.4-1.55 tons, metabolic energy – 92.65-103.84 GJ. The nutritional value on average for 4 cycles of bleaching on cereals and legume-cereal herbage with the use of fertilizers was 14.59–15.77% crude protein, 20.74-23.99% crude fiber, 24.14-26.74% ADF, 43.64-49.58% NDF.

1 Introduction

To provide cheap green animal feed and food for the population, a stable food base is needed, the basis of which is natural forage lands [1-4].

Traditional pastures are a key component of the landscape. They are increasingly appreciated for their important role in ensuring sustainable environmental development and positive results for society as a whole [5].

Pastures have a significant impact on soil water availability. At the same time, the root systems of perennial plants play an important role, which are crucial for the restoration of pasture ecosystems [6-8].

Perennial grasses are one of the main sources of feed due to their high productivity, the content of essential nutrients, compliance with the physiological needs of animals and high adaptability. In addition, they enrich the soil with organic matter. The popularization of perennial grasses is caused by their long service life, consistently high nutritional and productivity indicators in feed, cold resistance, the ability to restore vegetation cover, responsiveness to improving the quality of cultivation factors, the ability to increase protein content by growing cereals mixed with legumes or applying a sufficient amount of nitrogen fertilizers [9-13].

Perennial cereals or legumes require more basic nutrients in the soil, as they undergo repeated mowing in the early stages of growth, and also grow from early spring to late

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autumn. The long growing season makes it possible to exploit them as pasture crops and use them for forage: hay, pellets, briquettes, silage and haylage. [14].

The correct application of nitrogen, phosphorus and potash fertilizers for cultivated pastures has a positive effect to achieve high yields and quality of agricultural products.

The amount of mineral fertilizers used is determined by the type of soil, fertility and composition of the herbage. The main mineral fertilizers are applied during tillage before sowing. The main condition of the fertilizer system of cultivated plants at present is to reduce the energy costs of their use.

The appropriate use of fertilizers leads to an increase in soil fertility. It is also necessary to consider the intensity and duration of crop use, because the use of nitrogen fertilizers has a beneficial effect on the growth and protein content of grass sward. Therefore, the application of nitrogen fertilizers with greater efficiency will have an effect on cereal pastures. Pastures with a higher proportion of legumes (> 50%) when applying nitrogen fertilizer in spring do not give the expected result in yield growth [15].

The simultaneous use of nitrogen, phosphorus and potash fertilizers gives the greatest effect. At the same time, the most important problem is to find the optimal level and amount of fertilizer use, in the absence of negative effects on soil, plants and the environment [16].

In the experiment of Kovshova V.N. and Smirnova A. V. reasonable doses of mineral fertilizers are given for the improvement and care of long-term grasslands of pasture use. A high collection of digestible protein (937-1147 kg per 1 ha of pasture) on a permanent basis under various climatic conditions can be obtained only by providing top dressing of herbs with a complete mineral fertilizer at a dose of $N_{90}P_{60}K_{90}$ [17].

The purpose of the research is to study the effect of various doses of mineral fertilizers on the productivity and nutritional value of perennial grasses.

2 Materials and Methods of research

In the second decade of May 2022, the laying of scientific experience was carried out in the field of the North-West Research Institute of Dairy and Grassland Economy, a separate division of the FPFIS VolRC RAS according to the planned scheme in accordance with the methodological guidelines for conducting field experiments at the All-Russian Feed Research Institute n.a. V.R. Williams (Table 1) [18].

Table 1. Experiment scheme.

No.	Agrophytocenosis and seeding rate in kg/ha of 1st class seeds	Doses of fertilizers and biologics
1	Festulolium (6) + fescue (12) + timothy (8) + bluegrass (2)	no fertilizer
2	Festulolium (6) + fescue (12) + timothy (8) + bluegrass (2)	$N_{90}P_{60}K_{90}$
3	Festulolium (6) + fescue (12) + timothy (8) + bluegrass (2)	$N_{120}P_{60}K_{90}$
4	Festulolium (6) + fescue (12) + timothy (8) + bluegrass (2)	$N_{150}P_{60}K_{90}$
5	Festulolium (6) + fescue (12) + timothy (8) + bluegrass (2)	Bisolbi-T
6	Festulolium (6) + fescue (12) + timothy (8) + bluegrass (2)	$N_{90}P_{60}K_{90}$ + Bisolbi-T
7	Festulolium (6) + fescue (12) + timothy (8) + bluegrass (2)	$N_{120}P_{60}K_{90}$ + Bisolbi-T
8	Festulolium (6) + fescue (12) + timothy (8) + bluegrass (2)	$N_{150}P_{60}K_{90}$+ Bisolbi-T
9	Festulolium (6) + fescue (12) + timothy (8) + bluegrass (2)	$N_{90}P_{60}K_{90}$ + Extrasol
10	Festulolium (6) + fescue (12) + timothy (8) + bluegrass (2)	$N_{120}P_{60}K_{90}$ + Extrasol
11	Festulolium (6) + fescue (12) + timothy (8) + bluegrass (2)	$N_{150}P_{60}K_{90}$+ Extrasol
12	Festulolium (6) + fescue (12) + timothy (8) + bluegrass (2) + white clover (4)	$N_{45}P_{60}K_{90}$
13	Festulolium (6) + fescue (12) + timothy (8) + bluegrass (2) + white clover (4)	$N_{45}P_{60}K_{90}$ + Bisolbi-T

14	Festulolium (6) + fescue (12) + timothy (8) + bluegrass (2) + white clover (4)	$N_{45}P_{60}K_{90}$ + Extrasol

The scientific experiment consists of 14 variants in three-fold repetition, the area of one plot is 12 m^2. The mineral fertilizers used in the experiment are diammophoska, ammonium nitrate, potassium chloride. Mineral fertilizers were not applied to the cereal herbage of the first variant. In variants 2-4, 6-14, phosphorous and potash fertilizers were applied in spring at the beginning of the growing season at a dose of $P_{60}K_{90}$ kg/ha a.d.

Nitrogen application from the second to the fourth and from the sixth to the eleventh variants was carried out in several stages and in different doses:

-variants 2,6,9 in the spring - N_{40} kg/ha a.d., after the 1st and 2nd cycle of use of N_{25} kg/ha a.d.;

-options 3,7,10 in the spring - N_{60} kg/ha a.d., after the 1st and 2nd cycle of use for N_{30} kg/ha a.d.;

-options 4,8.11 in the spring - N_{80} kg/ha a.d., after the 1st and 2nd cycle of use of N_{35} kg/ha a.d.

Nitrogen was introduced in two stages on legume-cereal grass mixtures: in spring - N_{20} kg/ha a.d., after 1 cycle of use - N_{25} kg/ha a.d.

Agrochemical parameters of sod-podzolic, light loamy soil: pH_{KCl} – 5.2, humus – 2.3%, P_2O_5 – 236 mg/kg, K_2O – 119 mg/kg.

Soil preparation included winter plowing, 3-fold spring cultivation, rolling before sowing. The sowing period is early spring, with physical ripeness of the soil. Sowing was carried out with a seeder SN-16. The sowing method is in rows (15 cm), pure.

During the growing season, phenological observations were carried out (determining the phases of plant development), measuring the height of the herbage, determining the density of standing plants and shoots; accounting for the yield of perennial grasses with sampling for chemical analysis, analysis of the nutritional value of feed. When considering the harvest, samples of green mass were selected and analyzed for chemical composition analysis, carried out according to generally accepted methods by the staff of the CUC North-West Research Institute of Dairy and Grassland Economy. Nitrogen-free extractive substances (NFES), metabolic energy (ME), the content of feed units (f.u.), and digestible protein (DP) were calculated using the calculation method.

The weather conditions of the growing season in 2023 were generally favorable for the growth and development of forage crops (Figure 1, 2).

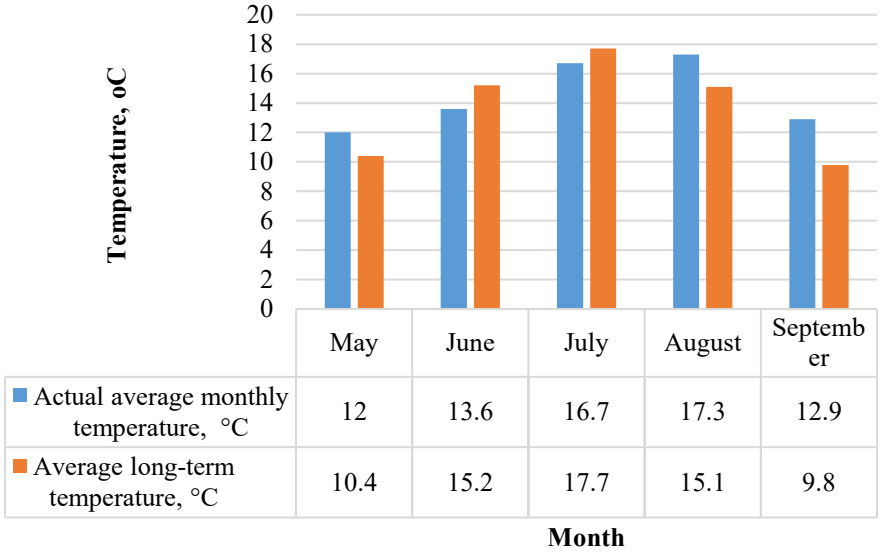

Fig. 1. Temperature in 2023.

The growing season was longer – in May, August and September, the average monthly temperatures exceeded the long-term average by 2-3°C. The average monthly temperatures in June and July were 1-1.5°C cooler than the average annual temperatures.

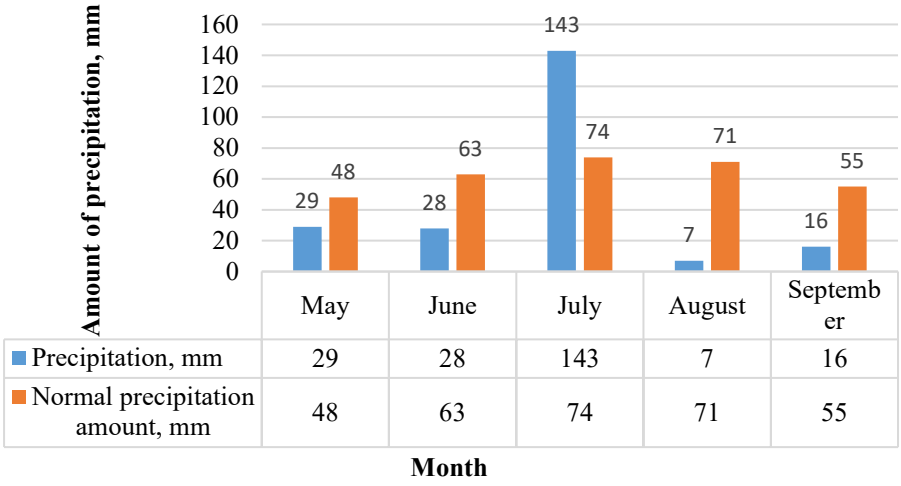

Fig. 2. The amount of precipitation in 2023.

The amount of precipitation in July was 193% of the annual average, but in the remaining months the amount of precipitation was significantly less than the annual average.

3 Results and Discussions

The beginning of the vegetation of cereals and legumes in 2023 was registered on April 12, and active regrowth of grasses was noted from the first decade of May. Four counts were carried out by the sloping method when the grassland reached pasture ripeness.

Phases of herb development before harvesting: cereals – tillering – exit into the tube; legumes (white clover) – budding.

The productive indicators of cereal and legume-cereal grasses of pasture use were determined by the conditions for their growth, depended on the adaptive ability, ecological plasticity and biological characteristics of the included species (Table 2).

Table 2. Productivity of pasture stands of the first year of use.

No.	Yield from 1 ha per season			
	dry weight, t	crude protein, t	exchange energy, GJ	crude fat, t
1.	2.55	0.25	25.23	0.05
2.	9.16	1.40	92.65	0.28
3.	9.99	1.50	99.44	0.28
4.	10.27	1.55	103.84	0.31
5.	3.1	0.32	30.49	0.07
6.	9.88	1.35	99.4	0.27
7.	10.69	1.56	108.83	0.30
8.	11.03	1.73	111.62	0.33
9.	9.98	1.41	100.72	0.27
10.	10.67	1.50	107.8	0.30
11.	10.32	1.62	105	0.31
12.	9.63	1.48	99.95	0.28
13.	9.67	1.38	99.72	0.29
14.	9.13	1.37	95.67	0.28
LSD_{05}	0.2 t/ha			

In total, during the season on cereal grass with the use of fertilizers, productivity amounted to 9.16-10.27 tons of dry weight, crude fat content 0.28-0.31 tons, crude protein 1.4-1.55 tons, metabolic energy – 92.65-103.84 GJ. Productivity indicators of legume-cereal herbage with the use of fertilizer differed slightly from those of the control variant. The yield of dry weight was 9.63 t/ha.

The conducted research in 2023 showed that the chemical composition and nutritional value of the studied legume-cereal herbages depended on their botanical composition, and cereals – on the use of mineral nitrogen fertilizers and microbiological preparations (Table 3).

Table 3. Nutritional value of pasture agrophytocenoses of the first year of use.

No.	Crude protein, %	Raw fiber, %	Raw fat, %	Metabolic energy, MJ
1.	10.26	23.27	2.48	9.8
2.	14.78	23.54	3.28	10.0
3.	14.59	23.99	3.09	9.9
4.	14.95	22.99	3.22	10.0
5.	10.63	23.31	2.47	9.8

6.	13.87	22.66	3.02	10.0
7.	14.47	22.29	3.08	10.1
8.	15.88	22.36	3.28	10.1
9.	13.79	22.99	2.94	10.0
10.	13.90	22.67	3.03	10.0
11.	15.52	22.49	3.14	10.1
12.	15.77	20.74	3.12	10.4
13.	14.45	20.98	3.15	10.3
14.	15.39	19.54	3.31	10.5

The nutritional value on average for 4 cycles of grazing on cereal grass with the use of fertilizers was 14.59-14.95% of crude protein, 22.99-23.99% of crude fiber. The amount of crude protein in the legume-cereal grass mixture with the use of fertilizers was 15.77%, and crude fiber was 20.74%.

The results of correlation and regression analysis and modeling of the effect of the dose of nitrogen (X) on the yield of the dry weight of the grass mixture (Y) are shown in Figures 3 and 4.

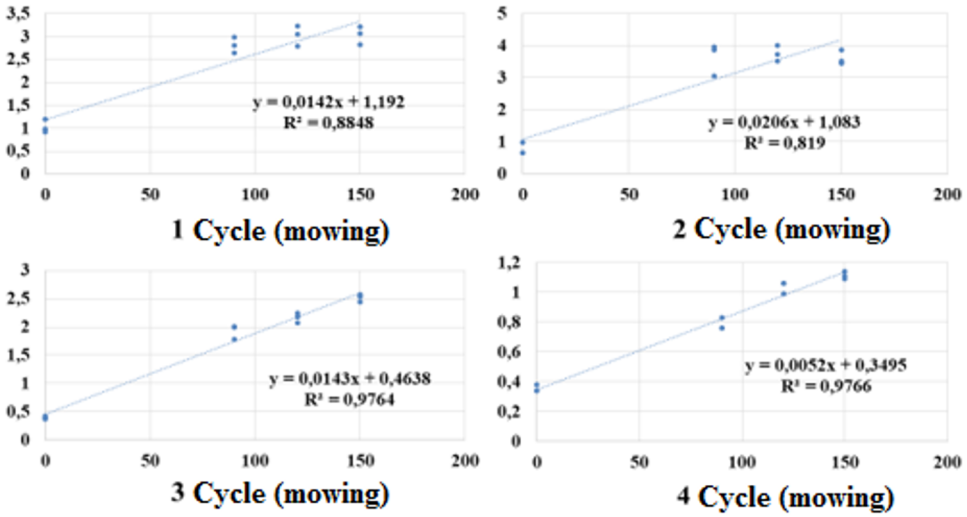

Fig. 3. Correlation fields between X (Nitrogen dose) and Y (yield of dry mass of grass mixture) according to the totality of samples 1-4 cycles.

According to the results of four mowing, there is a direct, very close correlation between yield and nitrogen dose. The obtained regression model indicates that with an increase in the dose of nitrogen application by 30 kg a.d., an increase in the yield of the dry mass of the grass mixture can be expected on average by 0.427 tons at the first mowing, by 0.619 tons at the second mowing, by 0.429 tons at the third mowing and by 0.157 tons at the fourth mowing.

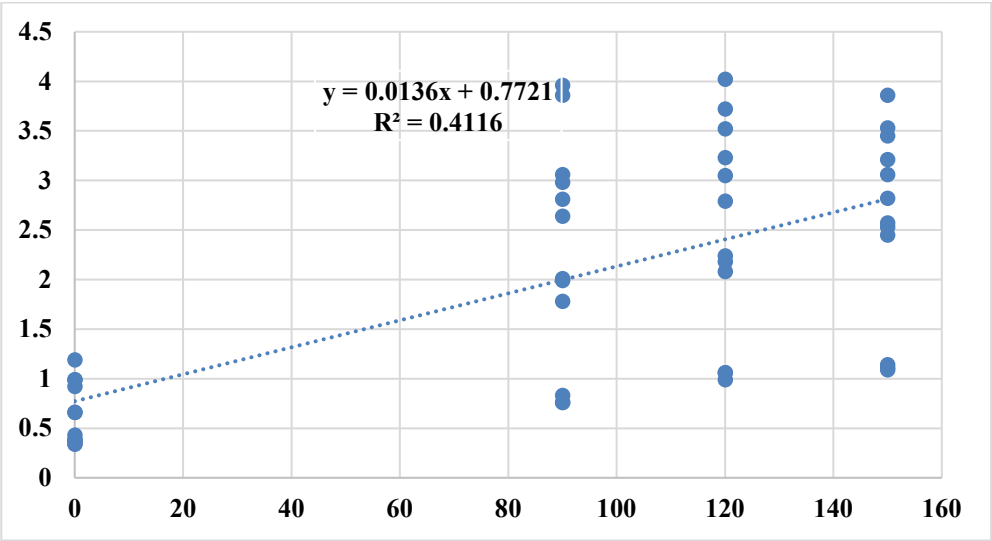

Fig. 4. Correlation field between X (Nitrogen dose) andY (yield of dry weight of grass mixture) according to the totality of samples of all cycles.

Summarizing the results of the experiment for all four mowings, we can talk about a noticeable effect of the nitrogen dose on the yield of the dry mass of the grass mixture, this factor explains the variation in yield values by 41.2%. The resulting regression model is statistically significant in accordance with the results of its analysis of variance and calculation of F-statistics (the calculated value is higher than the critical one, the significance level is almost zero). According to the model, it can be argued that with an increase in the dose of nitrogen application by 30 kg a.d., the yield increase can average 0.408 tons. The statistical significance of the model and the influence of the factor is confirmed by the Student and Fisher criteria.

The results of the study on the content of ADF and NDF in pasture agrophytocenoses are shown in Table 4.

Table 4. Content of the ADF and NDF for 2023, %.

Option number	1 accounting		2 accounting		3 accounting		4 accounting		average	
	ADF, %	NDF, %	ADF, %	NDF, %	ADF, %	NDF, %	ADF, %	NDF, %	ADF, %	NDF, %
1.	23.96	40.41	31.91	55.34	24.29	43.02	29.51	56.91	27.42	48.92
2.	24.93	49.33	25.35	47	21.88	42.99	31.27	56.88	25.86	49.05
3.	24.86	44.73	26.49	50.06	25.33	47.73	30.27	55.81	26.74	49.58
4.	29.95	46.91	24.61	47.13	21.71	41.19	27.67	52.36	25.99	46.90
5.	22.8	39.32	28.2	48.79	24.37	44.87	33.06	58.31	27.11	47.82
6.	29.01	48.4	25.67	47.12	21.61	41.38	26.5	50.25	25.70	46.79
7.	24.99	47.13	25.11	46.2	22.89	43.26	26.95	49.84	24.99	46.61
8.	24.81	45.86	25.79	47.57	22.98	43.63	26.21	47.57	24.95	46.16
9.	24.66	44.06	25.64	48.94	20.54	40.9	29.55	53.88	25.10	46.95
10.	24.03	44.01	25.61	47.58	21.58	41.72	26.58	50.29	24.45	45.90
11.	24.09	46.28	25.65	47.68	22.26	43.77	28.87	52.45	25.22	47.55
12.	21.4	40.21	26.08	49.08	20.95	38.77	28.13	46.51	24.14	43.64
13.	22.91	41.35	26.61	50.21	22.31	41.73	29.45	49.14	25.32	45.61

14.	22.12	40.18	27.63	41.43	21.48	38.82	25.97	41.07	24.30	40.38

An analysis of the average data on the study of the content of fiber fractions obtained during the experiment shows that when using mineral fertilizers in cereals and legume-cereal grass mixtures, the ADF was in the range from 24.14 to 27.42%, and the NDF was from 43.64 to 49.58%, which corresponds to the needs of highly productive animals [19].

4 Conclusions

An experiment was conducted on the effect of various doses of mineral fertilizers on the productivity and nutritional value of pasture stands. During the research, a noticeable effect of the nitrogen dose on the yield of the dry mass of the grass mixture was established. With an increase in the dose of nitrogen application by 30 kg a.d., the yield increase may average 0.408 tons. In total, during the season, 9.16-10.27 tons of dry weight, 0.28-0.31 tons of crude fat, 1.4-1.55 tons of crude protein, and 92.65-103.84 GJ of metabolic energy were obtained on cereal and legume-cereal herbages using fertilizers. On average, over 4 cycles of grazing, cereals and legume-cereal herbages with fertilization contained 14.59-15.77% crude protein, 20.74-23.99% crude fiber, 24.14-26.74% ADF, 43.64-49.58% NDF.

The author's scientific contribution of the study is embodied in the effect of mineral fertilizers on the productivity and nutritional value of cereals and legume-cereal grasslands of pasture use. In practice, the obtained research indicators contribute to the creation of a sustainable food base through the design and operation of cultivated pastures.

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