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# THE IMPROVEMENT OF *Nardus stricta* L. PERMANENT MEADOW FROM THE DORNA DEPRESSION THROUGH MINERAL AND ORGANIC FERTILIZATION

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***Abstract***

*In Romania, the grassland area dominated by Nardus stricta L. covers 200,000 hectares. Meadow degradation is caused by changes that occur in plant growing conditions and in the structure of vegetation. For long time, technological works and improvement measures were not applied on permanent meadows in Romania which led to a decrease in their production and to their degradation. The aim of this study was to evaluate the dynamics of productivity and quality of fodder, following the application of measures to stimulate and improve the production and quality of grasses on the permanent grasslands of Nardus stricta L. in the intramontane Depression of Vatra Dornei, from the North-Eastern Romanian Carpathians. At the same time, it was ensured that effects on the environment were minimal. The applied measures to Nardus stricta meadows, such as organic and mineral fertilization, led to a good plant growth and brought important changes in the chemical composition of the forage obtained (increase the content of CP and decrease the content of ADF and NDF). Thus, the quality and the digestibility of the feed improved significantly.*

***Key words****: Nardus stricta L. meadows, mulching, organic and mineral fertilizers, crude protein, forage quality.*

## INTRODUCTION

Grassland areas described as green oceans are important for the ecosystem services they may provide, such as: support, supply, cultural, and are the subject of several publications (Hopkins & Holz, 2005; Carlier et al., 2005; Lemaire et al., 2011; Boval & Dixon, 2012; O'Mara, 2012; Blair et al., 2014; Smit et al., 2015). The ability of grasslands to provide multiple ecosystem services largely depends on the intensity of the applied management (Galka et al., 2005; Hejcman et al., 2007a; Wang et al., 2014; Štýbnarová et al., 2010; Vîntu et al., 2011).

From Romania's almost 4,800,000 ha of meadows, 2,000,000 ha are grasslands of high natural value, which are generally located along the Carpathian Mountains. *Nardus stricta* L. meadows are Natura 2000 habitats and they hold a very important ecological paradox (Galvánek & Janák, 2008). The, *Nardus stricta* species is a widespread grass on plateaus and less inclined slopes, from the beech floor to the subalpine area, between 600 and 1800 m (Pușcaru-Soroceanu et al., 1963; Țucra et al., 1987; Chifu et al., 2014). It often develop monotonous meadows, almost monospecific or with a very small number of species (Vîntu et al., 2004), but the spread of *Nardus*-dominated meadows in the Carpathians is a phenomenon related to the massive expansion of sheep grazing in the mountains in the 20th century. The long period of grazing, the absence of fertilization, the severe climatic conditions led to the degradation of *Agrostis cappilaris* and *Festuca rubra* meadows, by infiltrating the phytocenosis structure of the species *Nardus stricta* L. with the formation of the sub-association *nardetosum strictae* (Marușca, 2021a). The productive potential of *Nardus stricta* meadows is low, and the forage obtained has a medium nutritional value. To improve the forage quality and productivity of these grasslands, ameliorative measures, especially fertilization, are of crucial importance (Hejcman et al., 2007b; Vîntu et al., 2015; Samuil et al., 2017; Blaj et al., 2019).

The main goal of the present study was to evaluate the effects of organic and mineral fertilization on the productivity of natural grasslands and the quality of forage. Also,

identifying economically efficient solutions for their sustainable use and for the conservation of biodiversity.

## MATERIALS AND METHODS

### *Soil and climatic conditions*

The experiment was conducted during 2021-2022 period, on a permanent meadow derived of *Nardus stricta* L., in the region of the North-Eastern Carpathians (Dorna Depression) at 845 m above sea level. The type of the soil (Photo 1) within the experimental field is represented by hyposkeletal luvosoil (Stănilă & Dumitru, 2016).

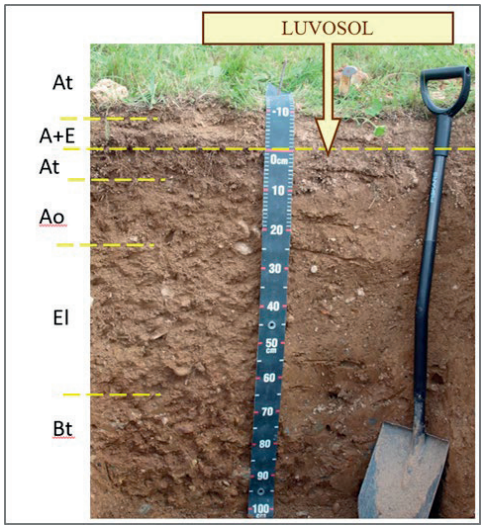



Photo 1. Soil profile of Luvosol within the field experimental

Within the luvosoil type, the well-developed sub-horizon with a thickness of 8-10 cm is noticeable (At), a horizon of accumulation of acid humus and lighter in color (Ao), the El horizon and the mineral horizon (Bt argic). The soil mountain-meadow is a luvosol hyposkeletal, belonging to the acid soils with pH of 4.2, and the land slope of 16º near a deciduous forest. The climatic conditions in the area are characterized by an average temperature of 6.3°C and 675 mm of total annual precipitation.

### *Experiment set-up*

A monofactorial experiment was organized after the randomized block method, in three replicates with the following variants:

$V_1$ - unfertilized (control);
$V_2$ - abandon (unharvested or non-grazing);
$V_3$ - mulching (cut and leave the biomass on site);
$V_4$ - $N_{50}P_{50}K_{50}$ kg/ha anually;
$V_5$ - $N_{100}P_{100}K_{100}$ kg/ha anually;
$V_6$ - $N_{150}P_{150}K_{150}$ kg/ha anually;
$V_7$ - 10 t/ha cattle manure, annually;
$V_8$ - 20 t/ha cattle manure, annually;
$V_9$ - 20 t/ha cattle manure, at 2 years;
$V_{10}$ - 30 t/ha cattle manure, annually;
$V_{11}$ - 30 t/ha cattle manure, at 2 years.

Two types of fertilizers were used: an organic one (well fermented cattle manure, older than 2 years) and a mineral one (a complex fertilizer with $N_{20}P_{20}K_{20}$). The cattle manure had the following chemical composition: N - 0.445%, $P_2O_5$ - 0.212% and $K_2O$ - 0.695%. Fertilizers were applied manually in early spring, before the start of active vegetation growth, respectively. The area of each (Table 1) variant was 12 $m^2$ (3 x 4 m), and the harvested area was 8.75 $m^2$ (2.5 x 3.5 m). The total experiment area was 396 $m^2$ (33 x 12 m).

Table 1. Experimental field parameters

| Parameter | Dimension |
|---|---|
| The area of a plot (variant) | 12 $m^2$ |
| The harvestable area of a variant | 8.75 $m^2$ |
| Number of replicates | 3 |
| Number of variants | 11 x 3 = 33 |
| The total area of the experience | 132 x 3 = 396 $m^2$ |

### *Measurements and analyses*

Harvesting was done at earing-flowering stage of the dominant grasses. The production evaluation on each experimental variant was performed by weighing of the resulted green mass and was reported per hectare. After determining the dry matter (DM) content of the forage, the production was expressed in tonnes per hectare DM. The DM content was determined by drying the grass in an oven at 103°C for 3 hours; work device: Heat-adjustable oven - Venticell 111 I; standard - SR ISO 6496/2001. Forage analyses were performed by the Laboratory *AgroLab* of the "Ion Ionescu de la Brad" Iași University of Life Sciences, Romania.

The total nitrogen (Nt), was analysed using the Kjeldahl method standard - SR ISO 13325/1995, and the crude protein content (CP) was calculated by multiplying the total nitrogen amount with the conversion factor 6.25; the content of the forage in neutral detergent fiber

(NDF), represented by hemicellulose, cellulose and lignin, was determined using the Van Soest method, according to the standard - SR ISO 16475/2004; the acid detergent fiber (ADF) content, represented by cellulose and lignin, was determined using the Van Soest method, according to the standard - SR ISO 13906/2008; the content of the analyzed samples in cell walls (ADF and NDF) was determined using the FibreBag-System, 36-place (Gerhardt analytical systems). Relative Forage Quality (RFQ) was calculated using the Equation 1 (Ward & Ondarza, 2008; Linn & Martin, 2012).

$$RFQ = \frac{DMI \times TDN}{1.23}$$

where:
- DMI (Dry Matter Ingested) = 120 / NDF (%)
- TDN (Total Digestible Nutrients) = 4.898 + 89.796 x NEL (%)
- NEL (Net Energy Lactation) = 1.085 - 0.0124 x ADF (Mcal/kg).

Equation 1. Relative Forage Quality

Yields and forage quality data were processed using ANOVA, applying the Least Significant Difference (LSD) test. Also, correlations were calculated (quadratic regression significance) between the type of fertilization and production of dry matter.

## RESULTS AND DISCUSSIONS

Researches carried out until today have demonstrated the positive effects of manure, as well as of mineral fertilizers applied reasonably on the meadows of *Nardus stricta* (Vîntu et al., 2011; Tarcău et al., 2012; Rotar et al., 2011). Yields were influenced by the rates and type of fertilizers applied. As, expected, the data on biomass yield, resulted from our study, indicated significant annual variation (Table 2). During the study period (2021-2022), the total biomass production responded very well to mineral and cattle manure application. Biomass production significantly increased with the addition of NPK or cattle manure in all treatments. We notice that the production achieved in 2021, in the unfertilized variant (control), was 1.16 t/ha DM, and the highest production in the same year, 4.38 t/ha DM, was recorded in the organically fertilized variant (30 t/ha cattle manure applied once every two years), with statistically ensured differences.

Meadows are important components of the Romanian ecosystems, being essential for their biodiversity. Despite the special value that biodiversity gives them, the meadows in the mountain area are threatened by degradation, including the risk of abandonment, due to the decline of traditional systems as a result of the decrease in livestock. Thus, large areas of meadows frequently remain ungrazed or unmowed, and the biomass left on the ground.

Table 2. The influence of organic and mineral fertilization on the dry matter production (DM), in 2021

| Experimental variants | DM production t/ha | Difference t/ha | Difference % | Significance |
|---|---|---|---|---|
| $V_1$ - unfertilized (control) | 1.16 | | 100 | Control |
| $V_2$ - abandon | - | | - | |
| $V_3$ - mulching | 1.22 | | 105.2 | |
| $V_4$ - $N_{50}P_{50}K_{50}$ kg/ha anually | 2.04 | | 175.9 | * |
| $V_5$ - $N_{100}P_{100}K_{100}$ kg/ha anually | 2.68 | | 231.0 | *** |
| $V_6$ - $N_{150}P_{150}K_{150}$ kg/ha anually | 2.93 | | 252.6 | *** |
| $V_7$ - 10 t/ha cattle manure, annually | 2.75 | | 237.1 | *** |
| $V_8$ - 20 t/ha cattle manure, annually | 3.13 | | 269.8 | *** |
| $V_9$ - 20 t/ha cattle manure, at 2 years | 3.51 | | 302.6 | *** |
| $V_{10}$ - 30 t/ha cattle manure, annually | 3.96 | | 341.4 | *** |
| $V_{11}$ - 30 t/ha cattle manure, at 2 years | 4.38 | | 377.6 | *** |
| | *LSD 5%* | *0.75* | | |
| | *LSD 1%* | *1.12* | | |
| | *LSD 0.1%* | *1.39* | | |

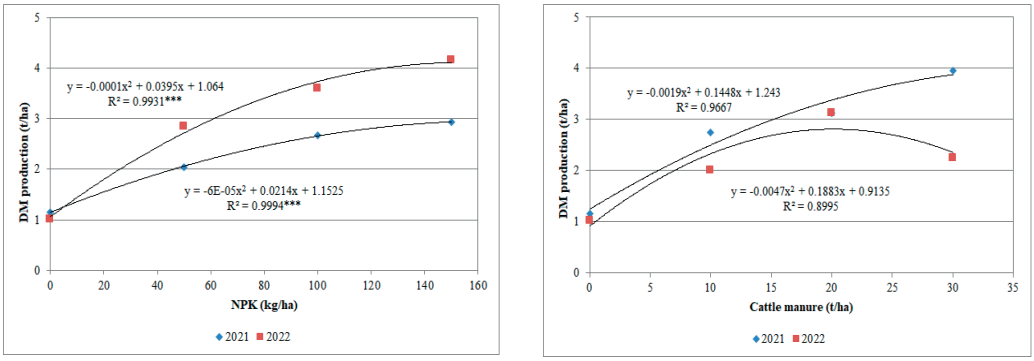
Considering these, it was proposed to study two variants (abandonment and mulch) in order to follow the changes that take place over time when no work is done on them. Therefore, in the

study year 2021, in the variant with mulch (cut and leave the biomass on site), the production of dry matter recorded was of 1.22 t/ha DM, with an insignificant difference compared to the control, as resulted from Table 2. The data recorded in the second year of study (2022) shows a significant decrease of the dry matter production (Table 3) compared to the previous year due to the severe climatic conditions (high temperatures and low precipitation). Also, in 2022, the realized productions were differentiated according to the doses and type of fertilizer. The mineral fertilization applied in different doses generated in this second year of the study higher yields compared to the previous one, and the highest production of dry matter, 4.51 t/ha DM, was recorded in the mineral fertilized variant with the maximum dose of NPK, respectively $N_{150}P_{150}K_{150}$ kg/ha, with a 305.1% increase in production compared to the unfertilized variant.

Table 3. The influence of organic and mineral fertilization on the dry matter production (DM), in 2022

| Experimental variants | DM production t/ha | Difference t/ha | Difference % | Significance |
|---|---|---|---|---|
| $V_1$ - unfertilized (control) | 1.02 | Control | 100 | Control |
| $V_2$ - abandon | - | - | - | - |
| $V_3$ - mulching | 0.92 | -0.10 | 90.1 | - |
| $V_4$ - $N_{50}P_{50}K_{50}$ kg/ha anually | 2.85 | 1.83 | 278.5 | *** |
| $V_5$ - $N_{100}P_{100}K_{100}$ kg/ha anually | 3.60 | 2.58 | 351.8 | *** |
| $V_6$ - $N_{150}P_{150}K_{150}$ kg/ha anually | 4.15 | 3.12 | 405.1 | *** |
| $V_7$ - 10 t/ha cattle manure, annually | 2.01 | 0.99 | 196.3 | *** |
| $V_8$ - 20 t/ha cattle manure, annually | 3.23 | 2.21 | 315.5 | *** |
| $V_9$ - 20 t/ha cattle manure, at 2 years | 2.60 | 1.58 | 254.1 | *** |
| $V_{10}$ - 30 t/ha cattle manure, annually | 2.25 | 1.23 | 219.7 | *** |
| $V_{11}$ - 30 t/ha cattle manure, at 2 years | 2.69 | 1.66 | 262.5 | *** |
| | *LSD 5%* | *0.42* | | |
| | *LSD 1%* | *0.58* | | |
| | *LSD 0.1%* | *0.79* | | |

In the second year of the study (2022) in the variant with mulch (cut and leave biomass on site), a dry matter production of 0.92 t/ha DM was recorded with an insignificant difference compared to the control variant (Table 3). Long-term improvement of *Nardus stricta* L. subalpine meadows can be achieved by applying medium chemical and organic fertilization (Blaj et al., 2019). Also, previous reported researches (Smits et al., 2008; Păcurar et al., 2010; Vîntu et al., 2015; Samuil et al., 2017; Cirebea et al., 2020, Gaga et al., 2022; Zornić et al., 2023) showed that mineral fertilization had a positive influence on production depending on the applied doses, which confirm the results of our study. Regarding the organic fertilization and its impact on the productivity of these type of meadows, previous reserches showed that, by applying a minimum of 20 t/ha, important production increases are realized (Rotar et al., 2011). The importance of fertilization for these types of meadows that were the object of our study was also highlighted by Vîntu et al. (2010), who followed the evolution of *Nardus stricta* L. meadows located in the Dorna Depression and found that the production of these meadows can be doubled by fertilization.
The values of the regression coefficient ($R^2$), for the dry matter production, in both years in which the study was carried out, were significant for mineral fertilization based on NPK as well as for cattle manure fertilization. It was found that the values of the regression coefficient ($R^2$) in the period (2021-2022), were very significant in the mineral fertilized variants with the doses of NPK and significant in the case of amount of cattle manure application (Figure 1 a, b).




a b

Figure 1 - a, b. Correlations between the type of fertilizer (doses of NPK and amount of cattle manure) applied and the dry matter production, in the 2021-2022 period

The influence of organic or mineral fertilization on forage quality is already known. Usually the forage's crude protein (CP) content varies depending on the plant species that are composing the crop or meadow and the fertilization. From a qualitative point of view, nitrogen fertilization contributes to increase the content of protein substances in feed, due to the nitrogen extracted in the protein composition (Dragomir, 2005). Therefore, during our study, the organic fertilization of *Nardus stricta* L. grassland using moderate amounts of 20 t/ha manure every year led to an increase in CP up to 11.39% in 2021 and up to 10.47% in 2022 compared to the control variant, unfertilized (Tables 4, 5).

At the same time, as it can be observed that there was a significant increase of 10.43% in 2021 and 10.31% in 2022 in $V_{10}$ (30 t/ha cattle manure, annually). Tarcău et al. (2012), within an experiment carried out on the same type of meadow, with mineral fertilization in several doses ($N_{100}P_{100}$, $N_{140}P_{140}$ and $N_{200}P_{200}$ kg/ha) show that there is a significant increase in CP content with increasing amounts of fertilizers, 6.48% la 6.59-14.08%. Also, similar results were obtained by Vîntu et al. (2015); Cirebea et al. (2020); Mrázková et al. (2020); Simić et al. (2020); Iliev et al. (2022).

The NDF and ADF values can influence the quality of the forage obtained from the pasture, as well as their effect on the animal feeding. These parameters are used to determin the nutritional value of the feed because the components of the cell wall - cellulose, hemicellulose and lignin are completely separated (Stybnarova et al., 2010).

Table 4. The influence of applied management on forage quality obtained from the *Nardus stricta* (L.) permanent meadow, in 2021

| Experimental variants | Quality parameters | | | |
|---|---|---|---|---|
| | CP (g·100 g$^{-1}$ DM) | NDF (g·100 g$^{-1}$ DM) | ADF (g·100 g$^{-1}$ DM) | RFQ |
| $V_1$ - unfertilized (control) | 8.54$^{C}$ | 59.70$^{C}$ | 48.93$^{C}$ | 78.19$^{C}$ |
| $V_2$ - abandon | - | - | - | - |
| $V_3$ - mulching | - | - | - | - |
| $V_4$ - $N_{50}P_{50}K_{50}$ kg/ha anually | 8.72 | 57.57$^{oo}$ | 43.60$^{ooo}$ | 91.14** |
| $V_5$ - $N_{100}P_{100}K_{100}$ kg/ha anually | 9.25* | 54.38$^{ooo}$ | 40.17$^{ooo}$ | 103.34*** |
| $V_6$ - $N_{150}P_{150}K_{150}$ kg/ha anually | 10.29*** | 51.06$^{ooo}$ | 38.89$^{ooo}$ | 112.78*** |
| $V_7$ - 10 t/ha cattle manure, annually | 9.24* | 58.59 | 45.14$^{ooo}$ | 86.70* |
| $V_8$ - 20 t/ha cattle manure, annually | 11.39*** | 50.77$^{ooo}$ | 39.23$^{ooo}$ | 112.69*** |
| $V_9$ - 20 t/ha cattle manure, at 2 years | 10.16*** | 56.26$^{ooo}$ | 45.14$^{ooo}$ | 90.29** |
| $V_{10}$ - 30 t/ha cattle manure, annually | 10.43*** | 53.03$^{ooo}$ | 39.23$^{ooo}$ | 107.89*** |
| $V_{11}$ - 30 t/ha cattle manure, at 2 years | 9.15 | 56.72$^{oo}$ | 44.23$^{ooo}$ | 91.30** |
| *LSD 5%* | *0.66* | *1.73* | *1.95* | *8.17* |
| *LSD 1%* | *0.93* | *2.38* | *2.68* | *11.26* |
| *LSD 0.1%* | *1.28* | *3.28* | *3.69* | *15.50* |

The forage content in NDF decreased significantly from 59.70%, in the case of the unfertilized control variant, to 58.59% and 50.77%, depending on fertilization, in 2021. The content in ADF show also a significant decrease from 48.93% (unfertilized control) to 45.14% and 38.89% in the case of fertilized variants (Table 4).

Table 5. The influence of applied management on forage quality obtained from the *Nardus stricta* (L.) permanent meadow, in 2022

| Experimental variants | Quality parameters | | | |
|---|---|---|---|---|
| | CP ($g \cdot 100\ g^{-1}$ DM) | NDF ($g \cdot 100\ g^{-1}$ DM) | ADF ($g \cdot 100\ g^{-1}$ DM) | RFQ |
| $V_1$ - unfertilized (control) | 7.93$^{C}$ | 56.11$^{C}$ | 49.34$^{C}$ | 82.40$^{C}$ |
| $V_2$ – abandon | - | - | - | - |
| $V_3$ – mulching | - | - | - | - |
| $V_4$ - $N_{50}P_{50}K_{50}$ kg/ha anually | 9.05* | 55.01 | 47.52 | 87.64* |
| $V_5$ - $N_{100}P_{100}K_{100}$ kg/ha anually | 9.37** | 53.70$^{oo}$ | 44.96$^{ooo}$ | 94.95*** |
| $V_6$ - $N_{150}P_{150}K_{150}$ kg/ha anually | 10.27*** | 51.85$^{ooo}$ | 43.10$^{ooo}$ | 102.24*** |
| $V_7$ - 10 t/ha cattle manure, annually | 9.86*** | 53.25$^{oo}$ | 48.60 | 88.33** |
| $V_8$ - 20 t/ha cattle manure, annually | 10.47*** | 51.98$^{ooo}$ | 42.68$^{ooo}$ | 102.86*** |
| $V_9$ - 20 t/ha cattle manure, at 2 years | 9.94*** | 52.37$^{ooo}$ | 44.73$^{ooo}$ | 97.84*** |
| $V_{10}$ - 30 t/ha cattle manure, annually | 10.31*** | 53.12$^{oo}$ | 43.70$^{ooo}$ | 98.57*** |
| $V_{11}$ - 30 t/ha cattle manure, at 2 years | 10.07*** | 54.52$^{oo}$ | 45.27$^{oo}$ | 92.91*** |
| *LSD 5%* | 0.99 | 1.58 | 2.21 | 4.16 |
| *LSD 1%* | 1.36 | 2.18 | 3.05 | 5.72 |
| *LSD 0.1%* | 1.87 | 3.00 | 4.20 | 7.88 |

Similar results were obtained in 2022 with a significant decrease in content of NDF from 56.11% (unfertilized variant) to values between 55.01% and 51.85%, depending on fertilization and, also, the ADF values from 49.34% (unfertilized variant) to 48.60% and 42.68%, which were influenced by the rates and type of fertilizers applied. In 2021 we obtained a higher crude protein content and lower values of fiber content (ADF and NDF) compared to 2022, suggesting the presence of other factors that could influence the quality of forage, such as climatic conditions. As in our case, the results obtained by Vîntu et al. (2011), Tarcău et al. (2012), Samuil et al. (2018), have shown that the fertilization of meadows of *Nardus stricta* L. with 20-50 t/ha of manure led an improvement of content ADF and NDF.

The mineral and organic fertilizers positively influenced the RFQ of the fodder, all fertilized variants of our study achieving increases with statistically assured differences, compared to the control variant. As it can be seen in Tables 4 and 5, regardless of the type of fertilizer, forage quality increased along with the applied doses in both years of the study. Thus, the RFQ values were between 102.24 and 112.69, which characterize a good forage quality, in the variant fertilized with 20 t/ha of cattle manure (annually) compared to values between 78.19 and 82.40, which characterize a poor quality of the feed, in the case of the unfertilized variant.

## CONCLUSION

The meadows of *Nardus stricta* L., being among the most degraded pastures in the Romanian mountains, they are the subject of a special concern regarding their economic value. Therefore, the identification of favorable solutions for their improvement is in the attention of researchers. Our research revealed the importance of organic and mineral fertilization for increasing the production of these meadows, as well as for increasing their yield and, at the same time, for improving the quality of the resulting fodder, a fact proven by the values of the chemical components and the parameters that characterize the fodder.

Thus, there was a significant increase in dry matter, crude protein, but also a decrease in the content of insoluble fibers and acid detergent fibers, respectively.

The values related to the relative quality of the fodder (RFQ) obtained in our study characterize a good quality of the fodder produced in the fertilized variants. The data obtained in this study could be useful in understanding the

nutritional potential of forages, representing basic information in ruminant nutrition. Our study shows that the fertilization of *Nardus stricta* L. meadows is the most effective technological measure for their improvement, and a fertilization with 20-30 t/ha cattle manure annually or with $N_{100-150}P_{100-150}K_{100-150}$ is very relevant.

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