SUBALPINE GRASSLANDS IMPROVEMENT METHODS DEGRADATION OF NARDUS STRICTA AFTER 30 YEARS OF APPLICATION IN THE CARPATHIAN MOUNTAINS OF ROMANIA

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Abstract

Experiments on the improvement of subalpine grasslands degraded by Nardus stricta through various surface and radical methods were carried out in the Bucegi Mountains at 1800 m altitude in the juniper (Pinus mugo). The paper analyzed the last 3 years (2023-2025) of the 30 experiments, started in 1995. There were no significant differences between the mineral, organo -mineral and organic fertilization factors on the production of dry matter (DM) which reached an average of 2.58-2.63 t/ha and crude protein (CP) which reached 287-305 kg/ha. Overseeding was 4.6% higher than the semi-natural grass carpet and reseeding was 1% lower than the control, for DM production, while for CP production the semi-natural variant was better. The most prolonged and strong effect was had by calcium amendment with very significant results of 21-25% higher than the unamended variants, even after 30 years. In the grassy carpet, improvement methods have produced profound changes in the sense of replacing the unvalued species Nardus stricta with Poa pratensis in the best variants of amendment and organic fertilization. Also, the sown species Phleum pratense survives vegetatively for over 30 years in the grassy carpet without reaching maturity in the subalpine layer of the Carpathians. Three-factorial experiments (3x3x2) applied to permanent grasslands can still provide surprising results as in the present work.

Keywords: *Nardus stricta* grasslands, improvement methods, DM and CP production, longevity

INTRODUCTION

Degraded grasslands of *Nardus stricta* are widespread in the Romanian Carpathians, especially in the mountainous area, where due to improper management and use they have replaced more valuable grasslands dominated *by Festuca nigrescens, Festuca rubra, Agrostis capillaris* and others (PUSCARU *et al*., 1956; SAFTA *et al*., 1962; SAMOILĂ, 1979; MARUȘCA, 1982; BĂRBULESCU and MOTCĂ, 1983). In this research, several methods of improvement were used through surface means, such as fertilization with mineral and organic fertilizers, calcium amendment, herbicides, etc., or radical works to replace the degraded grassy carpet with another more valuable forage by over-seeding or re-seeding with mixtures of perennial grasses. The experiments usually lasted 3-5 years, during which significant results were obtained in increasing feed production and quality. In the middle mountain area, through

calcium amendment and mineral or organic fertilization (mulching), in 2-5 years the degraded grassy carpet of *Nardus stricta* gradually evolved towards *Festuca rubra* and further *Agrostis capillaris*, satisfactory stage of evolution (MOTCĂ *et al.*, 1994).

Through total renovation, the productivity of these grasslands is further intensified, the grassy carpet with species from the spontaneous flora being replaced with improved varieties of perennial grasses and legumes (MARUȘCA, 1976, 1977).

This paper presents the long-term effect of calcium amendment, overseeding and reseeding, mineral and organic fertilization, of a *Nardus stricta* grassland under the climatic conditions of the Bucegi Mountains subalpine in the Southern Carpathians.

MATERIAL AND METHOD

Overall results

First, an overview of the results is presented before the analysis of variance considering the very large volume of data.

In this sense, the data of factor A (fertilization) are presented separately on the three graduations: mineral, organo - mineral and organic. The average production of all mineral fertilized variants (100) in 5 stages in 30 years, in the last 3 years was 2.63 t/ha dry matter (DM) and 305 kg/ha crude protein (CP) in which *Agrostis capillaris* dominates (37%), *Festuca nigrescens* (14%), *Poa pratensis* (12%), *Phleum grassland*, sown (6 %) and *Trifolium repens* (5 %) (Table 1).

The semi-natural unamended, mineral-fertilized grassland (111) with the lowest productivity (1.63 t/ha DM and 197 kg/ha CP) after 30 years is dominated by *Festuca nigrescens* (35%) and through total renovation (overseeding, reseeding) the production of DM increases by 59-63% and CP by 41-55%, the floristic composition being dominated by *Agrostis capillaris* (58-59 %) and the sown grassland specie *Phleum pratense* did not survive.

Between the overseeded and reseeded variants (120, 130) there are small differences in DM production (2.82-2.84 t/ha) but higher in CP in the overseeded variants (325 kg/ha) by 10% higher than in the reseeded ones (311 kg/ha). The factor with the greatest effect on productivity after 30 years was calcium amendment (102), when on average a 29% higher DM and 35% higher CP production was achieved compared to unamended variants, a result previously unknown in the literature.

Organo - mineral fertilization (200) had a different influence on the productivity of improved variants of *Nardus stricta* degraded grasslands compared to mineral fertilization (Table 2).

Thus, the highest average production of DM and CP was recorded in the variants with semi-natural grass carpet (210) compared to the over-seeded or re-seeded ones (220, 230) by 16-21%.

Table 1

Average dry matter and crude protein production of mineral fertilized variants (Average 2023-2025)

ABC variants	Production of DM		Forage species (%)					Crude protein (N x 6.25)	
	t/ha	%	1. *Agrostis capillaris*	2. *Festuca nigrescens*	3. *Poa pratensis*	4.* *Phleum pratense*	5. *Trifolium repens*	kg/ha	%
111	1.63	100	6	**35**	2	X	6	197	100
121	2.66	163	**59**	5	2	0	2	305	155
131	2.59	159	**58**	6	0	0	1	277	141
112	2.82	100	8	20	**45**	X	7	360	100
122	2.97	105	**40**	6	10	28	5	345	96
132	3.09	110	**50**	12	11	9	8	344	96
Mediate									
100	2.63	100	**37**	14	12	6	5	305	100
110	2.23	100	7	**28**	24	X	7	279	100
120	2.82	126	**50**	6	6	14	4	325	116
130	2.84	127	**54**	9	6	5	5	311	111
101	2.29	100	**41**	15	1	0	3	260	100
102	2.96	129	**33**	13	22	12	7	350	135

*) Species remaining from the original mixture

The variant with the highest productivity was 212 (semi-natural carpet, amendment) with 3.05 t/ha DM and 352 kg/ha CP, with a botanical composition dominated by *Poa pratensis* (53%) and *Trifolium repens* (28%) very valuable forage.

And in this case, the calcium amendment factor (202) after 30 years ensures an average increase of 15% for both DM and CP compared to the unamended variants (201).

Table 2

Average dry matter and crude protein production of organo-mineral fertilized variants (Average 2023-2025)

ABC variants	Production of DM		Forage species (%)					Crude protein (N x 6.25)	
	t/ha	%	1. *Agrostis capillaris*	2. *Festuca nigrescens*	3. *Poa pratensis*	4.* *Phleum pratense*	5. *Trifolium repens*	kg/ha	%
211	2.75	100	14	7	**53**	X	14	347	100
221	2.18	79	**42**	6	19	12	9	244	70
231	2.31	84	**53**	7	13	7	7	261	75
212	3.05	100	5	3	**53**	X	28	352	100
222	2.83	93	**30**	9	23	17	17	299	85
232	2.44	80	**28**	8	19	9	27	294	84
Mediate									
200	2.59	98.7	29	7	**30**	8	17	299	98.3
210	2.90	100	10	5	**53**	X	21	350	100
220	2.51	87	**36**	8	21	15	13	272	78
230	2.38	82	**41**	8	16	8	17	277	79
201	2.41	100	**36**	7	28	6	10	284	100
202	2.77	115	21	7	**32**	9	24	315	111

*) Species remaining from the original mixture

On the exclusively organically fertilized variants (300), in general, the factors improving grassland productivity behaved the same as those fertilized with organo -mineral fertilizers (200) (Table 3). Organic fertilization favorably influenced the over-seeded variants (320) where a 7% higher DM production was recorded compared to the semi-natural variants (310). Reseeded variants achieve a 6% lower DM production compared to the semi-natural variants, considered as a control. The highest DM production in the entire trifactorial experience is 3.19 t/ha in variant 322 with a balanced botanical composition: *Agrostis capillaris* (37%), *Phleum pratense* (19 %), *Trifolium repens* (19 %), *Poa pratensis* (15%) and *Festuca nigrescens* (5 %). The highest CP production was recorded in variant 312, semi-natural carpet, amended, organically fertilized, 370 kg/ha CP, where *Poa pratensis* (31%) and *Trifolium repens* (30 %) dominates.

The calcium amendment factor (302) ensured the highest increases, respectively 21% in DM and 26% in CP per hectare compared to the unamended one (301).

Table 3

Average dry matter and crude protein production of organically fertilized variants (Average 2023-2025)

ABC variants	Production of DM		Forage species (%)					Crude protein (N x 6.25)	
	t/ha	%	1. *Agrostis capillaris*	2. *Festuca nigrescens*	3. *Poa pratensis*	4.* *Phleum pratense*	5. *Trifolium repens*	Kg/ha	%
311	2.44	100	**33**	10	28	X	14	282	100
321	2.30	94	**48**	9	10	13	12	229	81
331	2.29	94	**48**	12	11	8	9	234	82
312	2.72	100	9	16	**31**	X	30	370	100
322	3.19	117	**37**	5	15	19	19	314	85
332	2.54	93	**39**	9	10	17	15	294	79
Mediate									
300	2.58	98.1	**36**	11	17	10	16	287	94.2
310	2.58	100	21	13	**30**	X	22	326	100
320	2.75	107	**43**	7	13	14	16	272	83
330	2.42	94	**44**	11	11	8	12	264	81
301	2.34	100	**43**	10	16	7	12	248	100
302	2.82	121	**28**	10	19	12	21	326	131

*) Species remaining from the original mixture

These results obtained through quantitative and qualitative determinations on average over 3 years (2023-2025) from the last 30 researches, confirm the results evaluated over 28 years based on floristic surveys on average over 5 years (2019-2023) published in the current journal, where the floristic composition and agrochemical properties of the soil were presented in more detail (MARUȘCA, 2024).

Analysis of variance of dry matter (DM) production

The analysis of variance of the DM production of the trifactorial experience (3x3x2) expressed by the F test is presented in Table 4.

Table 4.

Analysis of variance for dry matter (DM) production

Source of variation	SSP [SP]	Degrees of freedom	Amount weighted squares [s^2]	Test F		Meaning
				value	p	
A	0.0312	2	0.0156	0.129	0.878860	yes
B	0.2795	2	0.1398	1,161	0.320913	yes
C	4.5267	1	4.5267	37,597	0.000000	***
A*B	3.2871	4	0.8218	6,825	0.000160	***
A*C	0.2788	2	0.1394	1,158	0.321807	yes
B*C	0.3908	2	0.1954	1,623	0.206795	yes
A*B*C	1.2792	4	0.3198	2,656	0.042596	*
Error	6.5017	54	0.1204			
Total	16.5751					

*ns p>0.05; * p≤0.05;** p≤0.01;*** p≤0.001*

Similar to the data from the general presentation in tables 1, 2, 3, it is found that factor C (calcium amendment) is assessed as very significant as well as within the interaction between factors A x B (fertilization x grassy carpet), followed by a significant assessment for the interaction between all three factors studied (A x B x C). Factors A and B did not have a statistically significant influence on dry matter production. In order to know the residual effect of the improvement factors of these degraded *Nardus stricta* grasslands their graduations were statistically analyzed (Table 5).

Table 5.

Factor-level variance analysis for DM production, Average 2023-2025

Factor A. Fertilization	**SU**		**Diff . t/ha**	**Meaning**
	t/ha	**%**		
A1: Mineral (NPK) (100)	**2.63**	**100**	**mt**	
A2: Organo -mineral (PK-Paddocking) (200)	2.59	98.7	- 0.04	ns
A3: Organic (Paddocking) (300)	2.58	98.1	- 0.05	ns
DL 5% = 0.20 t/ha; DL 1% = 0.27; DL 0.1% = 0.53				
Factor B. Grassy carpet	**SU**		**Diff . t/ha**	**Meaning**
	t/ha	**%**		
B1: Semi-natural (Witness) (010)	**2.57**	**100**	**mt**	
B2: Overseeding (020)	2.69	104.6	0.12	ns
B3: Reseeding (030)	2.54	99.0	- 0.03	ns
DL 5% = 0.20 t/ha; DL 1% = 0.27; DL 0.1% = 0.53				
Factor C. Calcium amendment	**SU**		**Diff . t/ha**	**Meaning**
	t/ha	**%**		
C1: Unamended (Witness) (001)	**2.35**	**100**	**mt**	
C2: Amended 2/3 Ah (002)	2.85	121.3	0.50	***
DL 5% = 0.16 t/ha; DL 1% = 0.22; DL 0.1% = 0.28				

From these statistical analyses it results that the graduations of factors A and B are not significant at the end of 30 years of influence, with the exception of factor C in which calcium amendment is very significant, ensuring an average increase in DM production of 21.3%. Also, a slight superiority of 4.6% of the overseeded variants b2 (020) compared to the semi-natural variants b1 (010) is noted, as well as a 1% decrease of the reseeded variants, compared to the same control, b1, a fact also found in the evaluation based on floristic surveys (MARUŞCA, 2024).

The graphic expression of the influence of factors A, B, C with their graduations more clearly suggests the long-term effect (Figure 1).

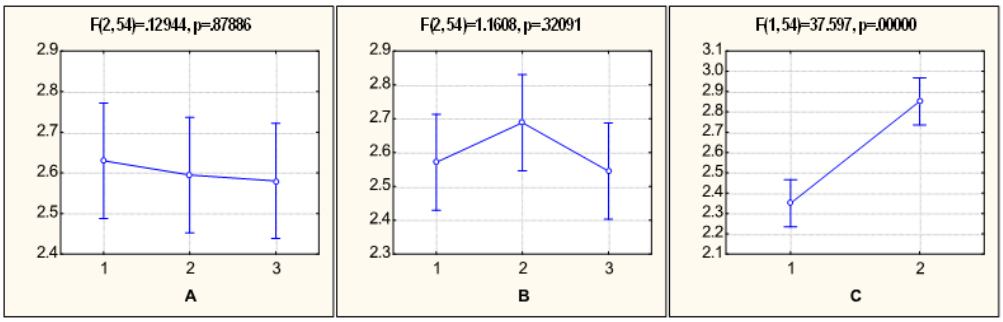

Fig.1. Influence of factors on DM production (t/ha)

A special result is represented by the percentage contribution of the factors and the interaction between them on the production of DM (Figure 2).

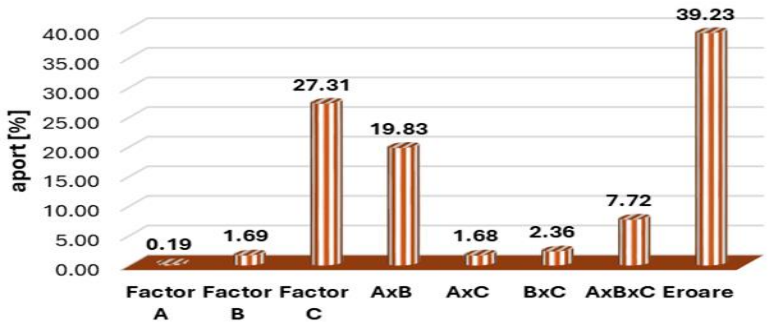

Fig. 2. Contribution of factors and interactions for the production of DM

From this graphic representation, the highest ratio (27.31%) of factor C (amendment) and the interaction A x B (fertilization, overseeding) (19.83%) on DM production is noted.

Analysis of variance of crude protein (CP) production

Similar to DM, analysis of variance was performed for crude protein (Table 6). From these data it follows that factor A (fertilization) and the interaction between A x C are significant and factors B (grass cover) and C (amendment) are highly significant.

Table 6.

Analysis of variance for crude protein (CP kg/ha)

Source of variation	SSP [SP]	Degrees of freedom	Weighted Mean Square [s^2]	Test F		Meaning
				value	*p*	
A	3976	2	1988	1,139	0.327780	ns
B	16140	2	8070	4,623	0.014020	*
C	78518	1	78518	44,980	0.000000	***
A*B	41678	4	10419	5,969	0.000472	***
A*C	11398	2	5699	3,265	0.045869	*
B*C	3427	2	1713	0.982	0.381295	ns
A*B*C	16948	4	4237	2,427	0.058891	ns
Error	94263	54	1746			
Total	266347					

In order to know the residual effect of the improvement factors of these degraded *Nardus stricta* grasslands on CP/ha, their graduations were statistically analyzed (Table 7).

Table 7.

Factor-level variance analysis for PB production, Average 2023-2025

Factor A. Fertilization	**PB**		**Dif.**	**Meaning**
	kg/ha	**%**	**kg/ha**	
A1: Mineral (NPK) (100)	**305**	**100**	**mt**	
A2: Organo -mineral (PK-Paddocking) (200)	299	98.3	-5	ns
A3: Organic (Paddocking) (300)	287	94.2	-18	ns
DL 5% = 24 kg/ha; DL 1% = 32; DL 0.1% = 42				
Factor B. Grassy carpet	**PB**		**Dif.**	**Meaning**
	kg/ha	**%**	**kg/ha**	
B1: Semi-natural (Witness) (010)	**318**	**100**	**mt**	
B2: Overseeding (020)	289	91.0	-29	*
B3: Reseeding (030)	284	89.3	-34	**
DL 5% = 24 kg/ha; DL 1% = 32; DL 0.1% = 42				
Factor C. Calcium amendment	**PB**		**Dif.**	**Meaning**
	kg/ha	**%**	kg/ha	
C1: Unamended (Witness) (001)	**264**	**100**	**mt**	
C2: Amended 2/3 Ah (002)	330	125.0	66	***
DL 5% = 20 kg/ha; DL 1% = 26; DL 0.1% = 34				

At the level of improvement factors with their residual effect on the amount of CP per hectare, mineral fertilization A (100) was on average 2-6% higher without being significant. In contrast, the semi-natural grassy carpet type B (010) is significantly superior after 30 years to overseeding (020) and distinctly significant to reseeding (030). As expected, the C (002) amendment factor is very significant compared to the non-amendment (001), ensuring a very large increase of 25% CP/ha. For a better understanding of the general

influence of factors A, B, C, a graphic expression of them was made (Figure 3).

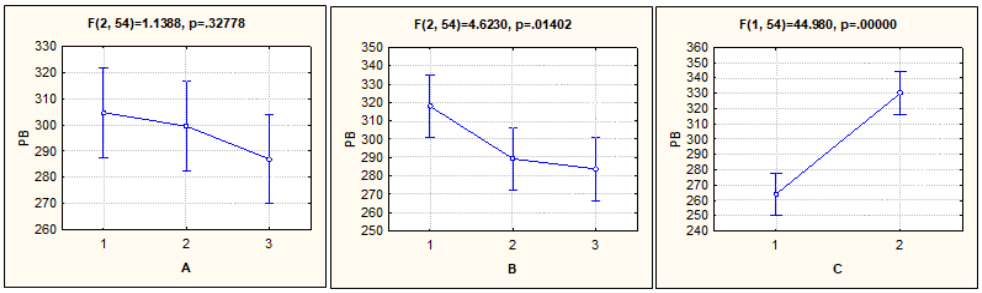

Fig. 3. Influence of factors on CP production (kg/ha)

The percentage contribution of factors and the interaction between them for achieving CP production is another important element resulting from variance analysis.

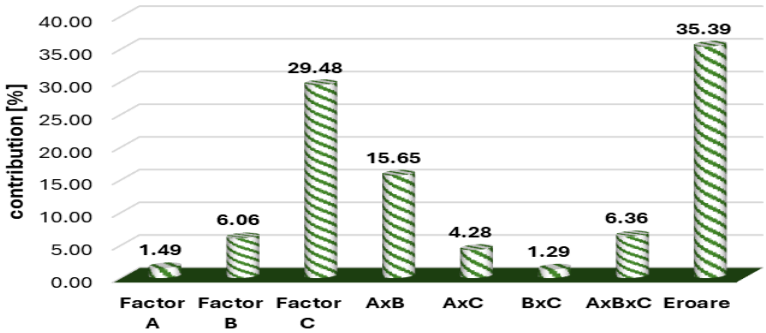

Fig. 4. Contribution of factors and interactions for crude protein (CP kg/ha)

From this graphic representation it results that calcium amendment (C) has the highest contribution (24.48%) followed by A x B with 15.65%, in achieving CP production per hectare, similar to the factors that influence DM production. The results on the long-term influence obtained through quantitative and qualitative determinations in the experimental field and laboratory fully confirmed the previous assessments of green mass production and pastoral value based on floristic surveys, both working methods complement each other.

CONCLUSIONS

The The factors improving subalpine grasslands degraded by *Nardus stricta* have a long-lasting effect on DM (t/ha) and CP (kg/ha) production with major changes in floristic composition.

After 30 years of mineral, organo - mineral and organic fertilization in 5 stages, the best results were obtained with organic fertilization (mulching).

The semi-natural grass carpet type in the last 3 years of the 30 experiments was generally superior to overseeding or reseeding, which have completed their biological lifespan with the exception of the sown species *Phleum pratense* which still survived.

Calcium amendment with lime dust has a very significant effect of 25% greater on the production of DM and CP compared to no amendment, even after 30 years, a fact less known until now.

Fertilization and calcium amendment after 30 years have removed the unvalued species *Nardus stricta,* replacing it with very valuable forage species such as *Poa pratensis, Festuca nigrescens, Agrostis capillaris, Trifolium repens* and others.

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