LONG-TERM EFFECT OF TECHNOLOGICAL IMPROVEMENT FACTORS OF SUBALPINE GRASSLANDS OF NARDUS STRICTA FROM THE CARPATIAS MOUNTAINS

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Abstract

For the improvement of subalpine grasslands degraded by Nardus stricta, several methods have been established based on experimental results of 3-5 years. Following a longer period of the effects of calcium amendment, over-sowing, re-sowing and the application of chemical and organic fertilizers bring more novelties that need to be known. In 1995, in the Bucegi Massif at 1800 m altitude, a three-factor experiment (fertilization, grass carpet type, calcium amendment) was placed, with excellent results. After 27 years, Phleum pratense sown in the mixture at a rate of 40% survived almost 26% in the overseeded, amended and chemically fertilized variant, a fact less known in the literature. In the semi-natural grass carpet, over 49% of Poa pratensis is installed on the amended and organo-mineral fertilized variant. The effect of calcium amendment lasts around 30 years compared to the known 8-10 years. The best option for improving the Nardus stricta subalpine grasslands was total weeding with glyphosate, calcium amendment, overseeding, initial chemical fertilization for 3 years, followed by organic (night paddocking), when more than 16 t/ha of green mass production was achieved, a loading of almost 3 UVM/ha with 85 indices of pastoral value and 4335 liters of cow's milk per hectare in a season of 85 transhumance days, evaluated in the period 2018 - 2022. Long-term experiments prove to be more than necessary in grasslands domain.

Keywords: *Nardus stricta* subalpine grasslands, improvement methods, forage production, forage quality, cow milk evaluation.

INTRODUCTION

Mountain grasslands in Romania are generally invaded by *Nardus stricta*, a non-valuable species that has gradually replaced other phytocoenoses dominated by *Agrostis capillaris*, *Festuca rubra*, *F. nigrescens*, *F. airoides*, etc., more valuable from a fodder point of view. (Pușcaru et al. 1956; Marușca 1982; Bărbulescu, Motcă 1983).

Research on methods of improving mountain grasslands degraded by Nardus stricta in the Carpathians through fertilization and calcium amendment rarely lasted more than three to five years (Pușcaru et al. 1956; Safta et al. 1962; Anghel et al. 1977).

The results of these fertilization, amendment and rational use experiences highlighted the replacement of *Nardus stricta*

species with other more valuable species such as *Festuca rubra*, *Agrostis capillaris* and many others.

Experiments to improve subalpine Nardus stricta grasslands by amending and fertilizing over a period of 12 years were carried out in the Bucegi Plateau with good results regarding the effect of calcium amendment and fertilization by sheep grazing (Maruşca 2021 a).

Less well known is the productivity with the long-term evolution of the improved grass carpet and by other methods such as those by overseeding and reseeding after destruction by total weeding or tillage of *Nardus stricta* fallow, main objectives of the present work.

MATERIAL AND METHOD

The experience was located in 1995 at the Blana - Bucegi Mountain Grasslands Research Base, located at 1800 m altitude, in the juniper subalpine layer (*Pinus mugo*), on a grassland with degraded grass carpet, in which Nardus stricta participated with over 60% and other species to a lesser extent.

At the beginning of the experiments, the agrochemical characteristics of the soil at the depth of 0-15 cm were 4.5 pH index in water; 22.0% V_{Ah}; 15.72% Humus; 18.5 ppm P-AL; 175 ppm K-AL and 4.788 me/100 g AL^{3+} soil, with extremely low fertility.

The variants of the long-term experience (1995-2022) were:

Factor A: Fertilization

1. Mineral fertilization

Stage I: 1996 - 50 kg /ha P_2O_5 +50 kg/ha K_2O;
1997 - 50 kg /ha P_2O_5 +50 kg/ha K_2O;
1998 - 50 kg /ha P_2O_5 +50 kg/ha K_2O;

Stage II: 2004 - 150 kg /ha N + 100 kg /ha P_2O_5 +100 kg/ha K_2O;
2005 - 100 kg /ha N;
2006 - 50 kg /ha N;

Stage III: 2012 - 150 kg /ha N + 100 kg /ha P_2O_5 +100 kg/ha K_2O;
2013 - 100 kg /ha N;
2014 - 50 kg /ha N;

Stage IV: 2017 - 150 kg /ha N + 100 kg /ha P_2O_5 +100 kg/ha K_2O;
2018 - 100 kg /ha N;
2019 - 50 kg /ha N;

2. Mineral and organic fertilization

Stage I: 1996 - 150 kg /ha N + 50 kg /ha P_2O_5 +50 kg/ha K_2O;
1997 - 100 kg /ha N + 50 kg /ha P_2O_5 + 50 kg/ha K_2O;
1998 - 50 kg /ha N + 50 kg /ha P_2O_5 +50 kg/ha K_2O;

Stage II: 2004 - Sheep night paddocking 5 nights 1 cow/ 6 m^2 + 100 kg /ha P_2O_5;

Stage III: 2011 - Bovine night paddocking 5 nights 1 cow/ 6 m^2 + 100 kg /ha P_2O_5;

Stage IV: 2017 - Bovine night paddocking 5 nights 1 cow/ 6 m^2

3. Organic fertilization

Stage I: 1995 - Sheep night paddocking 1 sheep/ 1 m^2 5 nights;

Stage II: 2004 - Sheep night paddocking 1 sheep/ 1 m^2 5 nights + 100 kg /ha P_2O_5;

Stage III: 2011 - Bovine night paddocking 1 cow/ 6 m^2 5 nights + 100 kg /ha P_2O_5;

Stage IV: 2017 - Bovine night paddocking 1 cow/ 6 m^2 5 nights

Factor B: Grass carpet

1. Seminatural (*Nardus stricta* 60 %);

2. Overseeding 1996, after total weeding (5 liters/ha Glyphosate) 1995 and harrowing (1-2 cm) and rolling;

3. Reseeding in 1996 after total weed control in 1995 and processing with a rolling mill (10-12 cm) before and after sowing;

Factor C: Calcium amendment

1. No amendment;

2. Amendment to 2/3 Ah (approx. 7,5 t/ha CaO)

For overseeding and reseeding, a mixture of perennial grass and leguminous seeds was used, consisting of: Phleum pratense Favorit variety (40%), *Festuca pratensis* Transilvan variety (25%), *Lolium perenne* Marta variety (5%), *Trifolium hybridum* - Braşov local population (15%), *Lotus corniculatus* Livada variety (15%), species absent from the spontaneous flora to distinguish the sown grassland from the semi-natural one.

The size of an experimental plot was 18 m^2 (6 m x 3 m). The number of repetitions was 4.

After the main species in the grassy carpet reached the sprouting-flowering stage, annual floristic observations were made by the author of the paper according to the KLAPP - ELENBERG percentage method and samples of 2 square meters were taken to determine forage production and quality. The remaining 16 square meters (89% of the area) of the experimental plot were actually grazed by dairy cows in order to get as close as possible to the real conditions of use of these subalpine grasslands.

In general, in experiments on the improvement of degraded pastures, harvesting was done by mowing, without the animal influence through trampling, breaking grass, droppings, etc.

Through this way of collecting samples and actually using this experience through grazing, the floristic evolution of the grass carpet during the 27 years of observations is closer to reality than that after mowing.

The floristic surveys carried out in the last 5 years (2018-2022) were the basis of the evaluation of the productivity of the grasslands (pastoral value and the green mass production) improved according to a new method presented and applied in this magazine which we will not return to (Marușca 2019, 2021 b; Marușca et al. 2019, 2020, 2021 a, b, c, 2022).

Also, based on the long-term results with dairy cows for 20 years in the same subalpine station from Blana - Bucegi, the formula was established by statistical calculation (Marușca et al. 2018).

RESULTS AND DISCUSSIONS

The technological factors studied had a strong influence on the agrochemical characteristics of the soil (Table 1).

Overall, after 20 years since the establishment of the experiment (1995), the soil reaction has increased on average by 0.6 pH units from 4.5 to 5.1; V_{Ah} by 18% from 22 to 40% and mobile Al decreased by 53% from 4.79 to 2.26 me/100 g soil.

The strongest influence on the soil was the calcium amendment which increased the average pH by 0.4 (4.9 - 5.3) the degree of saturation in V_{Ah} bases by 16.4% (31.8-48.2) and decreased Al^{3+} by 2.212 me/100 g soil.

The rest of the factors, such as fertilization and the type of grass carpet, after 20 years had a reduced influence on the agrochemical characteristics of the soil, with small differences of plus - minus 1 - 22% between them.

Table 1

The agrochemical characteristics of the soil according to the improvement methods of the subalpine grasslands after 20 years - Blana Bucegi 2016 (0-15 cm depth)

Variant A - fertilization B – grass carpet C - amendment	pH (H_2O)	AL^{3+} me /100 g soil	V_{Ah} (%)	Humus (%)	P-AL ppm (g/kg)	K-AL ppm (g/kg)
111	4,7	4,358	25,3	18,96	31,5	152
112	5,5	0,354	57,6	18,00	30,0	112
121	4,8	4,347	26,1	19,68	41,0	148
122	**5,7**	**0,156**	**63,0**	19,44	27,5	128
131	4,8	3,827	27,2	19,08	31,0	120
132	5,3	1,009	47,0	19,20	29,3	112
211	5,0	2,475	36,4	18,84	36,0	132
212	5,2	1,019	46,3	20,04	**92,0**	**154**
221	5,0	2,766	33,3	19,80	36,5	128
222	5,2	1,134	45,8	19,44	50,0	142
231	5,0	3,068	34,0	18,12	24,0	120
232	5,2	1,726	42,6	17,16	46,5	108
311	4,9	2,766	35,3	**20,52**	41,0	116
312	5,2	1,352	44,1	19,56	27,5	101

Variant A - fertilization B – grass carpet C - amendment		pH (H_2O)	AL^{3+} me /100 g soil	V_{Ah} (%)	Humus (%)	P-AL ppm (g/kg)	K-AL ppm (g/kg)
321		4,9	3,307	33,7	19,68	28,5	96
322		5,2	1,643	44,8	19,80	23,5	94
331		5,0	3,369	34,9	**20,52**	25,0	108
332		5,2	1,986	42,8	18,96	20,5	90
Average xxx		**5,10**	**2,259**	**40,0**	**19,27**	**35,6**	**120**
Average A	100	**5,13**	2,342	**41,0**	19,06	31,7	129
	200	5,10	**2,031**	39,7	18,90	**47,5**	**131**
	300	5,07	2,404	39,3	**19,84**	27,7	101
Diff. (%)	200-100	99	**87**	97	99	**150**	**102**
	300-100	99	103	96	104	87	78
	300-200	99	118	**99**	**105**	58	77
Average B	010	5,08	**2,054**	40,8	19,32	**43,0**	**128**
	020	**5,13**	2,226	**41,1**	**19,64**	34,5	123
	030	5,08	2,498	38,1	18,84	29,4	110
Diff. (%)	020-010	101	108	**101**	**102**	80	**96**
	030-010	100	122	93	98	68	86
	030-020	99	112	93	96	**85**	89
Average C	001	4,90	3,365	31,8	**19,47**	32,7	**124**
	002	**5,30**	**1,153**	**48,2**	19,07	**38,5**	116
Diff. 002-001	(+ ; -)	+ 0,40	- 2,212	+16,4	- 0,40	+ 5,2	- 8
	(%)	**108**	34	**152**	98	**118**	94

In contrast, the grass carpet, on average of the last 5 years (2018-2022) of the 27 years of existence, recorded major changes for the main component species (Table 2).

Thus, *Nardus stricta* remains in a reduced proportion only with chemical fertilization (Var.100), *Festuca nigrescens* reaches a maximum of 20% in variant 111, *Agrostis rupestris* with 11.5% and *A. capillaris* with 49.2 in variant 132 (chemical fertilization, reseeding, amendment), *Phleum pratense* with 40% at sowing time is maintained with 25.6% at variant 122 (chemical fertilization, overseeding, amendment), *Poa pratensis* with 49.4% at variant 212 (organo-mineral fertilization, natural grassland, amended), *Trifolium repens* with a maximum of 29% in variant 322 (organic fertilization, overseeding, amendment), *Ligusticum mutellina* and *Campanula serrata* better represented in variant 112 (chemical fertilization, natural grassland, amended).

It can be noted that the species *Campanula serrata*, protected at European level, is stimulated by calcium amendment on acidic soils and fertilization with chemical fertilizers, measures prohibited until now by those who deal with biodiversity conservation and environmental protection.

Table 2

The influence of improvement factors on the participation (%) in the grass carpet of the main species in the subalpine grasslands, Blana Bucegi - Average years 2018 -2022

Variant A - fertilization B – grass carpet C - amendment		*Nardus stricta*	*Festuca nigrescens*	*Agrostis rupestris*	*Agrostis capillaris*	*Phleum pratense**	*Poa pratensis*	*Trifolium repens*	*Potentilla ternata*	*Ligusticum mutellina*	*Campanula serrata*
111		**13,8**	**20,0**	3,0	3,4	0	0	4,4	5,4	1,6	1,8
112		0,1	15,6	0,6	2,4	1,4	39,0	14,4	3,2	**10,2**	**5,2**
121		4,2	10,0	8,0	34,4	0	0	2,2	**13,4**	2,2	1,8
122		0,1	11,2	5,8	29,8	**25,6**	10,2	8,0	1,8	2,0	1,4
131		9,4	7,6	11,4	34,0	0	0	1,4	8,6	1,4	1,2
132		0,8	6,8	**11,5**	**49,2**	8,5	8,2	9,0	2,2	2,2	0,6
211		0	15,0	0,1	1,0	0,1	47,2	14,6	2,5	1,6	1,0
212		0	7,2	0,6	5,6	0,2	**49,4**	21,2	0,1	1,0	2,2
221		0	6,0	8,6	27,0	16,0	20,4	12,0	1,0	1,8	0,2
222		0	4,4	1,6	16,2	21,2	24,2	24,0	0,2	0,8	1,6
231		0	12,0	4,6	34,8	9,4	8,0	14,6	1,6	0,2	3,2
232		0	8,6	1,4	24,0	15,0	16,0	23,2	0,1	0,1	0,1
311		0	13,6	1,2	13,2	0,1	28,4	16,2	2,2	4,6	2,2
312		0	9,4	0,1	0,1	0,4	44,2	25,6	0,4	6,4	3,4
321		0	10,8	5,4	31,8	13,4	13,8	15,6	1,4	1,4	0,8
322		0	8,2	2,0	19,8	16,0	14,4	**29,0**	0,6	0,6	1,9
331		0	12,6	5,4	38,2	11,8	6,2	13,6	0,8	0,1	1,6
332		0	5,8	5,6	26,8	17,2	12,8	23,0	0,1	0,1	1,0
Average xxx		**1,6**	**10,3**	**4,3**	**21,8**	**8,7**	**19,1**	**15,1**	**2,5**	**2,1**	**1,8**
Average A	100	4,7	11,9	6,7	25,5	5,9	9,7	6,6	5,8	3,3	2,0
	200	0	8,9	2,8	18,1	10,3	27,5	18,3	0,9	0,9	1,5
	300	0	10,1	3,3	21,7	9,8	20,0	20,5	0,9	2,2	1,8
Diff. (%)	200-100	x	75	42	71	**175**	**284**	277	16	27	75
	300-100	x	85	49	85	166	206	**311**	16	67	90
	300-200	x	**113**	**118**	**120**	95	73	112	**100**	**244**	**120**
Average B	010	2,3	13,5	0,9	4,3	0,4	34,7	16,1	2,3	4,2	2,6
	020	0,7	8,4	5,2	26,5	15,4	13,8	15,1	3,1	1,5	1,3
	030	1,7	8,9	6,7	34,5	10,3	8,5	14,1	2,2	0,7	1,4
Diff. (%)	020-010	30	62	578	616	**385**	40	**94**	**135**	36	50
	030-010	74	66	**744**	**802**	258	24	88	96	17	54
	030-020	**243**	**106**	129	130	67	**62**	93	71	**47**	**108**
Average C	001	3,1	12,0	5,3	24,2	5,6	13,8	10,5	4,1	1,7	1,5
	002	0,1	8,8	3,2	19,3	11,7	24,3	19,7	1,0	2,6	2,0
Diff. 002-001	(+ ; -)	-3,0	-3,2	-2,1	-4,9	+6,1	+10,5	+9,2	-3,1	+0,9	+0,5
	(%)	3	73	60	80	**209**	**176**	**188**	24	**153**	**133**

After evaluating the production and pastoral value based on the floristic survey for each individual variant, the milk production per hectare for transhumance cows on subalpine pastures improved by different methods was assessed (Table 3).

Table 3

Evaluation of grass production (GM/ha), grazing capacity (LU/ha) in 85 days, pastoral value (PV) and milk production (L/ha) according to the technological factors applied to the improvement of Nardus stricta subalpine grasslands from Blana Bucegi 2018 -2022

Variant A - fertilization B – grass carpet C - amendment	GM production (t/ha)	Animal loading LU/ha	Grazing capacity vs. average (%)	Pastoral value (PV)	Milk production (L/ha)	% to the average
111	5,24	0,95	42	50,6	2593	66
112	11,49	2,08	92	76,3	3910	100
121	7,45	1,35	60	60,2	3085	79
122	15,37	2,76	122	81,0	4150	106
131	6,86	1,24	55	65,9	3377	86
132	10,74	1,94	86	79,8	4089	104
211	13,10	2,37	105	76,9	3940	101
212	14,25	2,58	114	78,8	4038	103
221	14,71	2,66	117	84,1	4309	110
222	**16,27**	**2,94**	**130**	**84,6**	**4335**	**111**
231	12,72	2,30	102	77,6	3976	102
232	15,00	2,71	120	81,7	4186	107
311	11,55	2,09	92	75,3	3858	99
312	13,20	2,39	106	79,7	4084	104
321	14,55	2,63	116	81,7	4186	107
322	15,05	2,72	120	82,9	4248	109
331	13,13	2,38	105	76,8	3935	101
332	14,60	2,64	117	80,9	4145	106
Average ABC	**12,52**	**2,26**	**100**	**76,4**	**3915**	**100**

On average over the last 5 years (2018-2022) of the 27 experiments, the production of green mass (GM) reaches 12.52 t/ha, which allows a load of 2.26 LU/ha. On the same interval, the pastoral value (PV) reaches 76.5 and the milk production reaches 3915 liters per hectare in 85 days of grazing season. The best option for improving subalpine grasslands degraded by Nardus stricta is 222 (chemical and mineral fertilization, overseeding, calcium amendment) where 16.27 t/ha GM, 84.6 PV index and finally 4335 L/ ha cow's milk, a very good result. The individual influence of improvement factors on milk production is better represented in table 4, which confirms the previous results.

Table 4

The influence of technological improvement factors on productivity of the Blana Bucegi subalpine grasslands Average 2018-2022

A - fertilization B – grass carpet C - amendment		GM production (t/ha)	Animal loading LU/ha	Grazing capacity vs. witness (%)	Pastoral value (PV)	Milk production (L/ha)	% to the witness
Average A	100(Wt)	9,53	1,72	100	69,0	3534	100
	200	**14,34**	**2,59**	**151**	**80,6**	**4132**	**117**
	300	13,68	2,48	144	79,6	4076	115
Average B	010(Wt)	11,47	2,08	100	72,9	3737	100
	020	**13,90**	**2,51**	**121**	**79,1**	**4052**	**108**
	030	12,18	2,20	106	77,1	3951	106
Average C	001(Wt)	11,04	2,00	100	72,1	3695	100
	002	**14,00**	**2,52**	**126**	**80,6**	**4132**	**112**

Thus, variant 200, chemical fertilization in the first stage followed by organic fertilization by sheep or cows night paddocking proves to be the best in our case, because only by night paddocking we cannot reach more than 15 - 20% of the initial surface of the degrated grassland by *Nardus stricta* (Maruşca, 2016; Maruşca et al. 2010; Blaj et al. 2017).

The type of grass carpet most valuable for milk production proved to be the one with the minimum intervention on fallow from variant 020 (herbicide, overseeding), where *Poa pratensis* species from the spontaneous flora and *Phleum pratense* the Favorit sown variety hold the weight, a fact and noted in other previous works (Maruşca, 2017).

Similar results were also obtained on the Nardus stricta grasslands from Vlădeni - Braşov, where on average over 5 years (1968-1972), on the variants treated with Gramoxone (paraquat) 7.5 l/ha and overseeded with Rotaseeder, there was obtained a 22% higher forage production compared to the variants processed with the tiller at 10-12 cm or plowed at 18-20 cm (Maruşca, 1977).

In these two conditions, as grasslands invaded by Nardus stricta from Vlădeni (600 m alt.) and Bucegi (1800 m alt.), with acidic soils, rich in humus, the shallow processing of the fallow is superior to the deeper processing with the tiller or plow.

The application of amendments to correct soil acidity from variants 002 with favorable effect for over 27 years, has allowed the installation and expansion of more productive and better-quality species that influence direct milk production.

CONCLUSIONS

Experiments to improve the subalpine grasslands degraded by *Nardus stricta* need to be followed for more than 3 - 5 years, as is currently practiced;

Among the technological factors, calcium amendment can last around 30 years, the sown *Phleum pratense* species remain the same for 30 years and the last stage of grass carpet development seems to be *Poa pratensis* with rational fertilization and usage;

The best improvement option after 27 years was to destroy the degraded grass carpet by total weeding with glyphosate (5l/ha), amendment at 2/3 Ah, harrowing at 1-2 cm, overseeded with *Phleum pratense* based grass mix, chemical fertilization (150-100-50 N kg/ha 3 years on a unitary basis of 100 kg/ha P2O5 and 100 kg/ha K2O) followed by organic fertilization by night paddocking, when on average over the last 5 years, it was evaluated over 16 t/ha green mass production for 3 LU/ha, with 85 pastoral value index and 4335 liters of cow's milk per hectare in 85 days of transhumance.

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