LONG-TERM EFFECT OF THE TECHNOLOGIES AND RATIONAL USE OF *NARDUS STRICTA* SUBALPINE PASTURES FROM THE CARPATHIAN MOUNTAINS

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Abstract. *Between 1996 and 2020, in the Bucegi Mountains at 1,800 m altitude, 4 variants for improving subalpine grasslands degraded by Nardus stricta (40-60%) were investigated, namely A: control; B: chemical fertilization 3 years, followed by night paddocking once every 6 years; C: fertilization identical to B on soil amended in 1995 with lime dust and D: grassland sown in 1995, amended identical to C and fertilized identical to B and C. Each variant was used for 85 days by grazing with cows, and the milk production was recorded. The best variant on 25 years average was D (fertilized, amended, sown) where 5.51 t/ha SU and 4,640 liters of milk per hectare were recorded. The effect of amendment was 18-34% (variant C and D) and of the sown grassland (D) was of 14% to variant B, improved only by fertilization. Averaged over 25 years, the improvement works cost 4 Eurocents per liter of milk, representing 9.5% of the average milk price in 2022 of the European Union (42 Eurocents/Liter), our improvement works and usage with dairy cows having a high economic efficiency. Calcareous amendment lasts over 25-30 years and the sown grassland in subalpine conditions has an effect of about 20 years. Research will continue until the effect of calcium amendment is stopped, which is the most important improvement factor next to organo-mineral fertilization.*

Keywords: subalpine pastures, *Nardus stricta* grassy carpet improvement, usage with dairy cows, economic efficiency

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1. Introduction

The permanent grasslands from the subalpine gap of the Carpathian Mountains, with an area of approximately 200,000 hectares, are used for grazing with animals through transhumance [1].

In general, the subalpine grasslands are degraded, being invaded by Nardus stricta, a non-valuable species, which needs to be improved by various methods [1, 18].

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In recent decades, numerous long-term researches have been carried out in the Bucegi Mountains, regarding the improvement of the degraded grass carpet and the use of these grasslands by dairy cows.

Results published in the last two decades referred to dry matter production (DM) of improved subalpine grasslands and milk production in cows [4, 5, 6, 7, 8, 9, 10, 12, 15]; floristic composition [10, 11, 16, 17]; milk quality [3, 13]; climate influence [12]; the residual effect of the improvement factors after different periods [2, 13, 14, 16] and other aspects.

In the present work, a synthesis of the SU and cow's milk productions made in 25 years (1996-2020) is made, supplemented, for the first time, with an economic evaluation of the improvement works and rational use.

2. Materials and methods

The experiment was set up in 1995, at the Blana - Bucegi Mountain Grassland Research Station, located at 1800 m altitude in Moroieni commune, Dâmbovița County, using dairy cows that grazed on the four most important plots for grassland improvement, as follows:

1.Plot (Group) A: Permanent grassland (with *Nardus stricta* as dominant species) of 27 hectares, partially fertilized by night paddocking, rational pasturage with dairy cows (1996-2020).

2. Plot (Group) B: Permanent grassland (with *Nardus stricta* as dominant species) chemically fertilized in the period: 1996-1998 with a rate of 150 kg /ha N + 75 kg /ha P_2O_5 +75 kg/ha K_2O, then night paddocked with dairy cows in the years 2004, 2010, 2016 and 2022. Before or immediately after the night paddocking, the plot was chemically fertilized by superphosphate at a dose of 100 kg/ha P_2O_5.

3. Plot (Group) C: Permanent grassland (with *Nardus stricta* as dominant species), limed on 2/3 of Ah in the year 1995, chemically fertilized in the period 1996-1998 with a dose of 150 kg/ha N + 75 kg/ha P_2O_5 +75 kg/ha K_2O, then night paddocked with dairy cows in the years 2003, 2009 and 2021.

4. Plot (Group) D: Sown and limed pasture in the year 1995, chemically fertilized with NPK between 1996-1998 years, identical to plots B and C, and night paddocked with dairy cows in the years 2002, 2008, 2014 and 2020. Sowing was made with a mixture of perennial grasses and forage legumes consisting of: *Phleum pratense* Favorit variety (40%), *Festuca pratensis* Transilvan (25%), *Lolium perenne* Marta (5%), *Trifolium hybridum* - local population of Brasov (15 %), *Lotus corniculatus* Livada variety (15%).

One improvement plot covered a surface of 7,500 m^2/each, grazed by an average of three Brown Schwyz cows for a period of approx. 85 days. Each experimental

plot included three mobile metallic cages covering 2 m^2 and aiming to conserve the vegetation cover being also used for floristic, productivity and chemical analysis assessments

3. Results and discussions

Following the degraded by Nardus stricta grassy carpet improvement works through the activities mentioned in the previous paragraph, in the 25 years the production of dry matter (DM) was summed up, on averages of 5 years, to make it easier to compare their evolution in time (Table 1).

Thus, the production of SU in general in variants C (limed) and D (limed and seeded) has a slight decrease from the beginning of the experiments to the end due to the gradual decrease of the influence of calcium amendment and the reduction of improved species in the mixture of grasses sown in comparison with variant B (exclusively fertilized).

The strongest effect of calcium amendment was recorded in the period 6-10 years (2001 - 2005), when variant C produced 5.17 t/ha SU and D, a production of 7.95 t/ha SU, the highest in 25 experimental years.

Table 1) The influence dynamics of the main technological improvement factors on the production of dry matter (DM)

Period	Average of 5 years	Variant					
		B	**C**		**D**		
		Prod. DM t/ha	Prod. DM t/ha	Liming effect (%)	Prod. DM t/ha	Effect %	
						Limed	Sown
1996 - 2000	**5**	**3.28**	**3.82**	**116**	**4.71**	**144**	**123**
2001 - 2005	5	3.91	5.17	132	7.95	203	154
1996 - 2005	**10**	**3.60**	**4.50**	**125**	**6.33**	**176**	**141**
2006 - 2010	5	3.00	3.67	122	5.64	188	154
1996 - 2010	**15**	**3.40**	**4.22**	**124**	**6.10**	**179**	**145**
2011 - 2015	5	3.76	4.36	116	4.70	125	108
1996 - 2015	**20**	**3.49**	**4.26**	**122**	**5.75**	**165**	**135**
2016 - 2020	5	3.97	3.63	91	4.57	115	126
1996 - 2020	**25**	**3.58**	**4.13**	**115**	**5.51**	**154**	**133**

Next, the effect of calcium amendment weakens constantly, but does not disappear entirely.

In the version improved only by fertilization, considered a witness for improvement technologies, the productions from 5 to 5 years are quite uniform being between 3.28 - 3.97 t/ha DM, on average 3.58 t/ha DM.

Through liming and fertilization (C), production increases by 15% compared to the control (B) and in the sown variant (D) the increase reaches 54% on average for 25 years.

The effect produced by technology-sown grasslands (var. D) is maximum between 2001 - 2010, the production being 54% higher than the grass carpet with spontaneous species (var. C), after which it decreases continuously.

Cow milk production generally follows DM production with some small variations (Table 2).

Table 2. The dynamics of cow milk production according to the technological factors for the improvement of the grass carpet degraded by *Nardus stricta*

Period	Media pe ani	Variant					
		B	**C**		**D**		
		Milk prod. L/ha	Milk prod. L/ha	Liming effect (%)	Milk prod. L/ha	Effect %	
						Limed	Sown
1996 - 2000	**5**	**3,652**	**4,418**	**121**	**4,709**	**129**	**107**
2001 - 2005	5	2,291	3,259	142	4,617	202	142
1996 - 2005	**10**	**2,972**	**3,839**	**129**	**4,663**	**157**	**122**
2006 - 2010	5	3,700	4,073	110	4,485	121	110
1996 - 2010	**15**	**3,214**	**3,917**	**122**	**4,604**	**143**	**118**
2011 - 2015	5	3,257	3,700	114	4,472	137	121
1996 - 2015	**20**	**3,225**	**3,863**	**120**	**4,571**	**142**	**118**
2016 - 2020	5	4,378	4,880	112	4,924	112	101
1996 - 2020	**25**	**3,456**	**4,066**	**118**	**4,641**	**134**	**114**

In general, as organically fertilized by night paddocking progresses the grassy carpet quality improves and milk production increases.

The maximum effect of calcium amendment on milk production is the same after 5 years from the start of the experiment (2001-2005), being 42% higher in the spontaneous grass carpet (C) and double in the sown grassland (D) compared to the control (B).

On 25 years average, the highest milk production is in variant D, where 4641 liters/hectare was recorded, with a 34% liming effect and a 14% sowing effect compared to variant B, taken as a control.

At the end of the analyzed period (2016 - 2020) the sown grassland, in terms of milk production, falls to the same level as the production of the spontaneous grass carpet.

Another important element in our experiments is the specific consumption of DM to make one liter of milk (Table 3).

Average DM consumption was around 1 kg per 1 liter of milk with small fluctuations for variants B and C with spontaneous grass carpet and slightly larger differences for variant D with sown grassland.

The DM requirement higher by 14-17% to produce one liter of milk in option D, compared to options B and C, can have two explanations, one related to the understocking of animals per hectare and the second, to the reduction of the biodiversity of the grassy carpet in the sown grassland case, aspects that need to be clarified in future research.

Table 3. Specific consumption of dry matter (DM) from pasture to produce one liter of cow's milk

Average results (no. of years)	Lot (kg SU/ 1L milk)			Effect %		
				Limed		Sown
	B	C	D	C	D	D
5	0.90	0.86	1.00	96	111	116
10	1.21	1.17	1.36	97	112	116
15	1.06	1.08	1.32	102	124	122
20	1.08	1.10	1.26	102	117	115
25	1.04	1.02	1.19	98	114	117

A final aspect of the grassland's productivity improved by different methods (options B, C and D) is to compare them with option A (rational grazing, partially night paddocked) and option T (extensive grazing, degraded grasslands) (Table 4).

Table 4. Comparative data on the influence of improvement methods in 25 years on the productivity of subalpine grasslands

Variant (Cow lot)	DM production			Cow milk production		
	Average t/ha	% to		Average L/ha	% to	
		T	A		T	A
T* - witness *Nardus stricta* de 40-60%	1.20	100	x	846	100	X
A** - rational grazing, partially night paddocked	1.93	161	100	1,224	145	100
B***- NPK fertilized + night paddocked + grazed	3.58	298	185	3,456	409	282
C***- limed + NPK + night paddocked + grazed	4.13	344	214	4,066	481	332
D*** - limed + sown + NPK + night paddocked + grazed	5.51	459	285	4,641	549	379

* T= the herd outside the experimental field in the Bucegi plateau with data from 1996-1999, with a load of 0.6 LU/ha/85 days

** A = the group of cows grazing in the experimental field on 27 hectares in the period 1996-2020, with a load of 1.2 LU/ha/85 days of grazing

*** B, C, D = the group of cows grazing in the period 1996-2020, with a load of 4 LU/ha/85 days of grazing

The production of the subalpine grasslands invaded by Nardus stricta (40-60%) outside the experimental device was 1.2 t/ha DM, of very poor quality, where 846 l/ha of cow's milk was recorded.

Only by adjusting the optimal load with dairy cows, non-mixing with grazing sheep and partial night paddocking, in the 25 years of experience, in variant A, DM production increased by 61% and milk production by 45%, compared to non-rational grazing, traditional, from the T variant.

By applying the known improvement measures and rational grazing with dairy cows in variants B, C and D, the production of DM and milk increases progressively, being 4.6 times higher in DM and 5.5 times higher in milk, in the best variant, variant D, compared to variant T, extensive grazing, currently traditional.

Finally, the long-term experiment also allowed a short economic analysis of the technologies of improvement and use in relation to the value of the animal product obtained (Table 5).

Table 5. The amount of influence of the investment regarding the improvement of the grass carpet and rational use of the degraded grasslands on the cost of milk

Variant	Investments on materials and works	Total estimated value € /ha	Effect duration ani	Annual estimated value €/ ha/an	Average milk production L/ an	Eurocents* per 1L milk/an
A. Fencing, rational grazing	Fences	**1,500**	**50**	**30**	**1,224**	**2.5**
B. Complex fertilization (15-15-15) 330 kg/ha and ammonium nitrate 300 kg/ha for 3 years	Fences	1,500	50	30	**3,456**	0.4
	Fertilization	2,050	25	82		0.9
	TOTAL:	**3,250**	**x**	**112**		**3.2**
C. Liming 7 t/ha CaO + NPK for 3 years	Fences	1,500	50	30	**4,066**	0.7
	Fertilization	2,050	25	82		2.1
	Liming	1,200	30	40		1.0
	TOTAL:	**4,750**	**x**	**152**		**3.8**
D. Sowing perennial grasses 35 kg/ha + CaO + NPK for 3 years	Fences	1,500	50	30	**4,641**	0.6
	Fertilization	2,050	25	82		1.8
	Liming	1,200	30	40		0.9
	Sowing	875	25	35		0.7
	TOTAL:	**5,500**	**x**	**187**		**4.0**

*Average exchange rate 1€ = 4.9 lei

The calculation elements per hectare of the improvement works were expressed in euros to be easier to understand and generalize (Table 5).

Thus, for fencing with a fixed fence for rational grazing in all variants (A,B,C,D), a cost of 1,500 €/ha was estimated, for chemical fertilization (B,C,D) in the first 3 years, 2,050 € /ha, for the amendment with lime dust (C and D) at the beginning of the experiments, 1,200 €/ha and for the establishment of the sown grassland (D), only once, at the beginning of the experiment, 875 €/ha.

Depending on the duration of the effect of these investments and improvement factors, the annual value was estimated, which was related to the average milk production achieved during the 25 years of experimentation on each individual improvement variant.

Taking into account the average value of a liter of milk, in the middle of 2022, at EU level, which was 42 Eurocents, it was possible to establish the share of improvement works, which is 9.5% in the best option, D plot, 9% for C plot, 7.6% for B plot and 6% for A plot.

Obviously, in the end, the best and most economical variant is that of D plot (fertilized, amended, sown) where 4641 liters/ha/year are achieved, with a value of €1,950/ha, on average over 25 years, 3.8 times larger compared to version A (partially night paddocked).

Conclusions

(1). On the subalpine grasslands located at 1800 m altitude, in the Carpathian Mountains, currently degraded by *Nardus stricta*, through lime dust amendment, NPK chemical fertilization, reseeding and further, night paddocking, 5.5 t/ha DM can be achieved on average over 25 years and 4,640 liters of cow's milk per hectare in 85 days of grazing.

(2). The effect of the amendment on the production of DM and milk is over 30 years, and of the sown grassland, around 20 years, data less known in the specialized literature and practice.

(3). The annual expenditure for the improvement and rational use of grasslands reaches almost 190 €/ha/year, returning 4 Eurocents (9.5%) per liter of cow's milk from the 42 Eurocents current price at EU level, which is very profitable.

R E F E R E N C E S

[1] Bărbulescu, C., Motcă, Gh.. Grasslands of the highest muntains (Păşunile munţilor înalţi), In Romanian. Ceres Publishing House, (1983).

[2] Blaj, V. A., Marușca, T., Mocanu, V., Dragomir, N., Constantinescu, S., Rechițean, D., The remanent effect of treatments applied on subalpine grasslands grazed by dairy cows on milk production. Scientific Papers Animal Science and Biotechnologies, Vol. 47 (2), USAMV Timișoara (2014).

[3] Blaj, V. A., Marușca, T., Andreoiu, A. C., Mocanu, V., The long-term effect on cow's milk quality of methods for improving subalpine grasslands. 19th Symposium of the European Grassland Federation, EGF, Vol. 22,416-418, Alghero – Italy, 7-10 May, (2017).

[4] Maruşca, T., Pop, M., Neagu, M., Mocanu, V., Les lots demonstratifs aves des vaches laitieres en alpage et leur importance pour la diffusion des resultats de la recherche. FAO-CIHEAM, 10 eme reunion du Grupe de travail des herbages de montagne,10-13 septembre, Braşov – România (1998).

[5] Marușca, T., Pop, M., Neagu, M., Mocanu, V., Blaj, V. A., Oprea, G., Effects of the technologies for improving the subalpine grasslands on the production of dairy cows (Efectul tehnologiilor de îmbunătăţire a păşunilor subalpine asupra producţiei vacilor de lapte). Symposium "Scientific Research and sustainable agriculture (Cercetarea ştiinţifică şi agricultura durabilă)", Academy of the Romanian Scientists, 93-102, AGRIS Publishing House, Bucureşti (2001).

[6] Marușca, T., Mocanu, V., Blaj, V. A., Effect of improvement technologies on subalpine pastures in milk production of dairy cows. Proceedings of the 19th General Meeting of the European Grassland Federation, Multi – Function Grasslands, Grassland Science in Europe, Vol. 7, 1052-1053, La Rochelle, France (2002).

[7] Marușca, T., Blaj, V. A., Preliminary results concerning the producing of organic cow milk on the grasslands from the Bucegi Plateau (Rezultate preliminare privind producerea laptelui de vacă "ecologic" pe păşunile din Platoul Bucegilor), Scientific Papers SC " CCEDER" SA Cristian Sibiu (Lucrări ştiinţifice S.C. "CEDER" S.A. Cristian Sibiu), Vol. II, pp.39 – 44, Mira Design Publishing House, Sibiu (2003).

[8] Marușca, T., Mocanu, V., Blaj, V. A., Contributions regarding the improvement of subalpine pastures by grazing with milk cows in Bucegi Mountains. Timisoara`s Academic Days, VIIIth Edition, Scientifical Papers, Faculty of Agriculture, Vol. XXXV, pp. 205-210, Mirton Publishing House, Timişoara 92003b).

[9] Marușca, T., Mocanu, V., Blaj, V. A., Research regarding to obtaining of milk cow for agri-tourism ecological methods in Bucegi Plateau, Journal of Eco-AgriTourism, Proceeding of BIOATLAS, Conference Vol 1,"Transilvania" University of Brasov, pp.80-84, (2008).

[10] Maruşca, T., Blaj, V. A., Mocanu, V., Cardasol, V., Oprea, G., The utilization of improved subalpine pastures by grazing dairy cows. Romanian Journal of Grassland and Forage Crops, The Romanian Society for Grassland RJGFC No. 1/ 2010, pp. 33-44 (2010).

[11] Maruşca, T., Dragomir, N., Mocanu, V., Blaj, V. A., Tarjoc, F., Dragomir, C., Constantinescu, S., Effect of some improvement works on the floristic composition of the vegetal cover in Nardus stricta grasslands, Scientific Papers Animal Science and Biotechnologies, Vol. 47 (1), USAMV Timişoara, pp. 144-150 (2014).

[12] Maruşca, T., Blaj, V. A., Mateescu, E., Mocanu, V., Haş, C. E., Influence of climatic condition on the production of cow milk in subalpine improved pastures from Bucegi. Romanian Journal of Grassland and Forage Crops, No. 9, pp 59-68, Cluj – Napoca (2014a).

[13] Maruşca, T., Mocanu, V., Blaj, V. A., Haş, C. E., Andreoiu, A. C., Long term influence of reseed grasslands on organic milk production in subalpine floor. Romanian Journal of Grassland and Forage Crops Nr.10, Pp.33-43, Cluj – Napoca (2014b).

[14] Maruşca, T., Andreoiu, A. C., Blaj, V. A., Mocanu, V., Haş, C. E., Long term effect of improvement methods on subalpine degraded Nardus stricta L. grasslands, Annals, Series Agriculture, Vol. 4. No. 1-2, Academy of the Romanian Scientists Publishing House, Bucureşti, pp.42-49 (2015).

[15] Maruşca, T., Blaj, V. A., Mocanu, V., Ene, T. A., Andreoiu, A. C., Dragoş, M., M. M., Zevedei, P. M., An efficient system of organic farming on mountain grasslands from Carpathian. Journal of Mountain Agriculture on the Balkans, Vol. 19, pp.42- 52, Published by: Research Institute of Mountain Stockbreeding and Agriculture, Troyan, Bulgaria (2016).

[16] Maruşca, T., Blaj, V. A., Mocanu, V., Andreoiu, A., C., Zevedei, P. M., Long term influence of botanical composition of alpine pastures on cow milk production, Proceedings of the 27th General Meeting of the European Grassland Federation, EGF, Vol.23, pp. 283-285, Cork, Ireland, 17-21 June, (2018).

[17] Maruşca, T., Multiannual dynamics in species composition and productivity of an ammeliorated subalpine grassland managed with dairy cow, Romanian Journal of Grassland and Forage Crops , Cluj Napoca, No. 24, pp. 51-61. (2021).

[18] Puşcaru, D., Puşcaru-Soroceanu, E., Păucă, A., Şerbănescu, I., Beldie, Al., Ştefureac, Fr., Cernescu, N., Saghin, F., Creţu, V., Lupan, L., Taşcenco, V., Alpine grasslands from the Bucegi Mountains (Păşunile alpine din Munţii Bucegi), Romanian Academy Publishing House, Bucureşti (1956).