# STUDIES CONCERNING THE RESIDUAL EFFECT OF FERTILIZATION AND AMENDMENTS ON THE FLORISTIC COMPOSITION AND PRODUCTIVITY OF SUBALPINE GRASSLANDS

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**Abstract.** *This manuscript aims to provide a first study on the effect of long-term (12 years) calcium amendment and chemical and organic fertilization (sheepfold) on the subalpine grasslands located in the Bucegi Mountains (at 1800 m altitude). The productivity of the improved grasslands was determined on the basis of floristic survey and specific pastoral indices. The results achieved highlighted increases in the pastoral value which doubled its value from 34 on control plot compared with the plots treated with amendment and fertilization. The green mass production increased threefold from 2.76 t/ha at the control plot compared to the calcium amended and chemically or organically fertilized plots. Our results evaluated a possible dairy milk production of 2,500 - 3,500 liters per hectare in a season of 85 days as a result of feeding animals with grass from the pasture, under the open sky. Calcium amendment and sheepfold treatments seemed to have the highest economic effect in the conditions specific to the subalpine floor of the Carpathians Mountains.*

**Keywords:** *Nardus stricta* grasslands, calcium amendments, chemical fertilization, sheepfold, dairy milk

## 5. Introduction

The subalpine grasslands found in the Romanian Carpathians, located at altitudes ranging between 1,600 - 1,800 m up to 2,000 - 2,200 m, and comprising an area of 200 - 250 thousand hectares, resulted mainly from the deforestation of spruce rarities (*Picea excelsa*) and juniper bushes (*Pinus mugo*) [1].

A large percentage of these grasslands comprise a degraded vegetation cover, caused mainly by the invasion of *Nardus stricta* non-valuable species, and thus require the application of improvement methods [12].

The most well-known methods for grassland improvement include the fertilization with chemical fertilizers and sheep folding, as well as calcium amendment used to correct the acid reaction of the soil [4, 5, 6, 7].

The reevaluation of some old data sets on the residual effect of fertilization and amendment was made through floristic survey and by establishing some pastoral

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coefficients for milk production for the subalpine floor [9, 10]. Thus, this manuscript provides for the first time a productivity assessment of the subalpine grasslands located on Bucegi Mountains (improved by fertilization and amendment) on the basis of floristic surveys and pastoral coefficients.

## 6. Material and methods

The studies were performed within the Mountain Research Base Blana-Bucegi, on a degraded subalpine *Nardus stricta* grassland, located at 1,800 m altitude, on the territory of Moroieni commune, Dâmbovița County.

The experimental design comprising a bi-factorial experience (2 x 3), 18 $m^2$/plot/replicate includes:

Factor A: Calcium amendment

1. Control plot
2. Amended at 2/3 Ah (7,5 t/ha CaO)

Factor B: Fertilization

1. Control plot
2. Fertilized with 150 N + 50 P2O5 + 50 K2O, three years consecutive
3. Sheepfold 5 nights/one adult sheep/$m^2$/one time.

The correction of soil acidity through amendments and sheepfolds were performed in the spring of the year 1996. The treatments with chemical fertilizers were applied in the years 1996, 1997 and 1998 as follows: fertilization with phosphorus and potassium was done in autumn; fertilization with nitrogen was made in the spring. The capitalization of grassland production relied on grazing with dairy cows.

The floristic surveys were performed for all the experimental plots, comprising a period of 12 years (between the years 1997-2008). The floristic surveys were made after the KLAPP-ELEMBERG method.

Considering the large volume of collected data, the floristic surveys were grouped for 3 years, respectively the first 3 years (1997-1999) were used for assessing the immediate effect on grassland productivity while the following 3 years (2000 - 2008) were used for assessing the residual effect of the experimental factors studied. Due to the prolonged effect of amendments, sheep folding and even chemical fertilization, an assessment of productivity for the improved grassland was finally made considering the entire experimental period.

The evaluation of grassland productivity was made after a new method based on floristic surveys which scores some forage quality and green mass indices to the species found in the grassy carpet.

The optimal loading with animals was made on the basis of forage green mass production (GM), after the formula (1):

$$UL/ha = -\frac{GM(kg/ha)}{Grazing.period(days)X\,65kg/head/day} \quad (1)$$

The production of dairy milk per ha was calculated considering the pastoral value (PV) multiplied with the pastoral coefficient - for subalpine grassland - for milk (51.24, statistically assured), comprising a period of 20 years.

## 7. Results and discussions

Soil agrochemical properties changed as a result of calcium amendments and sheep folding applied in the year 1996 and under the influence of chemical fertilization with NPK for 3 consecutive years (Table 1).

**Table 4)** Soil agrochemical composition on 15 cm layer, as influenced by amendments and fertilization applied to subalpine grasslands from Blana - Bucegi 2000

| *Specification* | *UM* | *Experimental plot* | | | | | | | | *Difference A2-A1* | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | A1 without amendments | | | | A2 with amendments | | | | | |
| | | Mt. | NPK | Org. | Average | Mt. | NPK | Org. | Average | +; - | % |
| pH in H2O | Ind. | 4.8 | 4.8 | 4.9 | 4.8 | 5.4 | 5.7 | 6.3 | 5.8 | +1.0 | 121 |
| VAh | % | 25.7 | 26.6 | 30.0 | 27.4 | 51.7 | 60.7 | 85.3 | 65.9 | +38.5 | 241 |
| IN | % | 14.04 | 14.4 | 14.25 | 14.1 | 13.71 | 13.82 | 11.66 | 11.06 | -1.05 | 93 |
| Humus | Ind. | 3.61 | 3.73 | 4.27 | 3.87 | 7.09 | 8.39 | 9.94 | 8.47 | +4.60 | 219 |
| $P_2O_5$ | ppm | 19.8 | 25.0 | 27.0 | 23.9 | 23.5 | 31.0 | 28.0 | 27.5 | +3.6 | 115 |
| $K_2O$ | ppm | 90 | 103 | 134 | 109 | 133 | 119 | 150 | 134 | +25 | 123 |
| $Al^{+3}$ | me/ 100g | 4.16 | 4.14 | 3.86 | 4.05 | 1.00 | 0.40 | 0 | 0.47 | -3.68 | 12 |

Our results show that the amendment application increased soil reaction with a pH unit from 4.8 (very acid) to 5.8 (moderate acid). This treatment affected also the

degree of saturation with basis ($V_{Ah}$) which increased two times, and the P and K content which increased with 15-23% compared to the control plot, without amendment application. A very important indicator which in high amounts could be toxic for plants is the mobile aluminum. The results recorded in this experiment showed that the plots treated with amendments scored a lower mobile aluminum content, from 4.16 me/100 g soil on experimental plot 11 (control plot, without treatment) up to 0 me/100 g soil on experimental plot 23 (amended and sheep folded).

The results of floristic surveys highlighted 30 plant species important for the grassy carpet, including 12 plant species from *Poaceae* family, 1 from *Fabaceae* and 17 from other botanical families (Table 2).

The average data recorded during the first three experimental years highlighted a regression in *Nardus stricta* species, from 35.5% until 18.0% as a result of amendments, and until 1.6% as a result of chemical fertilization with NPK. In the same time our results pointed out that the application of amendments and sheep folding resulted in the disappearance of *Nardus stricta* species from the experimental plot.

**Table 5)** Floristic composition and productivity assessment of the ameliorated grassland in the first 3 experimental years (1997-1999) (% participation) Blana-Bucegi

| Plant species | Indices | | Experimental plot | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Without amendments | | | Amended | | |
| | F | M | 11 (Ct.) | 12 (NPK) | 13 (sheepfold) | 21 (Ct.) | 22 (NPK) | 23 (sheepfold) |
| ***Poaceae*** | | | | | | | | |
| *Agrostis capillaris* | 7 | 5 | - | - | 2.6 | - | 3.0 | 4.6 |
| *Agrostis rupestris* | 5 | 1 | 11.9 | 8.1 | 1.3 | 12.0 | 4.5 | 1.4 |
| *Anthoxanthum odoratum* | 5 | 3 | 0.1 | 1.4 | 2.2 | 0.1 | 0.1 | 0.2 |
| *Deschampsia caespitosa* | 3 | 0 | - | 0.1 | 1.3 | - | 1.1 | 0.9 |
| *Deschampsia flexuosa* | 4 | 3 | 4.3 | 2.3 | 0.9 | 2.6 | 0.5 | 1.4 |
| *Festuca nigrescens* | 7 | 5 | 1.1 | 5.1 | 26.0 | 1.3 | 12.1 | 17.6 |
| *Festuca ovina* | 5 | 4 | 6.2 | 23.5 | 6.5 | 8.8 | 7.0 | 2.3 |
| *Nardus stricta* | 3 | 0 | 35.5 | 1.6 | 1.3 | 18.6 | 0.1 | - |
| *Phleum alpinum* | 6 | 3 | 2.0 | 9.5 | 4.3 | 2.1 | 10.1 | 6.0 |
| *Poa annua* | 7 | 2 | - | - | 0.4 | - | - | 5.1 |
| *Poa media* | 5 | 2 | 10.0 | 32.4 | 12.1 | 11.6 | 13.7 | 10.2 |
| *Poa pratensis* | 8 | 6 | - | - | 9.9 | 5.5 | 5.0 | 3.7 |
| ***Fabaceae*** | | | | | | | | |
| *Trifolium repens* | 8 | 5 | 3.6 | 0.5 | 11.2 | 15.1 | 20.1 | 23.2 |

*Table 2 continuation*

| Plant species | Indices | | Experimental plot | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Without amendments | | | Amended | | |
| | F | M | 11 (Ct.) | 12 (NPK) | 13 (sheep folding) | 21 (Ct.) | 22 (NPK) | 23 (sheep folding) |
| ***Other botanical families*** | | | | | | | | |
| *Achillea stricta* | 6 | 6 | - | 0.1 | - | - | - | - |
| *Alchemilla xanthochlora* | 6 | 2 | . | . | 0.4 | . | . | . |
| *Campanula abietina* | 3 | 0 | 0.6 | . | . | . | . | . |
| *Campanula serrata* | 3 | 0 | 0.1 | . | 0.9 | 0.5 | 1.0 | 1.0 |
| *Cerastium fontanum* | 3 | 0 | 0.1 | 0.1 | 1.7 | 0.5 | 3.0 | 2.3 |
| *Geum montanum* | 3 | 0 | 0.1 | 0.1 | . | 0.1 | 0.1 | 0.1 |
| *Hieracium aurantiacum* | 4 | 2 | 0.6 | 0.1 | . | 0.6 | 0.1 | . |
| *Ligusticum mutellina* | 7 | 1 | 8.1 | 10.4 | 10.8 | 17.5 | 13.2 | 13.0 |
| *Luzula multiflora* | 4 | 2 | 0.1 | . | . | 0.1 | . | 0.1 |
| *Polygonum bistorta* | 5 | 4 | . | . | . | 0.1 | . | . |
| *Potentilla ternata* | 3 | 0 | 10.4 | 4.5 | 3.9 | 2.7 | 5.1 | 2.8 |
| *Ranunculus montanus* | 1 | 0 | 0.1 | 0.1 | 0.4 | 0.1 | 0.1 | 0.5 |
| *Stellaria graminea* | 1 | 0 | . | . | 0.1 | . | . | 0.5 |
| *Taraxacum officinale* | 7 | 3 | . | . | 1.3 | . | . | 2.8 |
| *Veratrum album* | 1 | 0 | . | . | . | . | . | 0.1 |
| *Veronica chamaedris* | 3 | 0 | . | . | 0.4 | . | . | 0.1 |
| *Viola declinata* | 4 | 1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| Forage species | x | | 53.0 | 93.4 | 90.0 | 77.4 | 89.5 | 91.7 |
| Harmful species | x | | 47.0 | 6.6 | 10.0 | 22.6 | 10.5 | 8.3 |
| **Pastoral value** | **(ind)** | | **34.0** | **56.6** | **66.6** | **53.9** | **65.5** | **70.0** |
| Relative value | % | | 100 | 166 | 196 | 159 | 193 | 206 |
| **Forage production** | **GM t/ha** | | **2.76** | **5.46** | **8.38** | **4.82** | **7.49** | **8.04** |
| Relativ value | % | | 100 | 198 | 304 | 175 | 271 | 291 |

As showed in Table 2, some more rustic forage species such as: *Agrostis rupestris* and *Deschampsia flexuosa* showed significant decreases in their participation in the vegetation cover.

The fertilization with NPK seemed to be favoring the appearance of *Poa media, Festuca ovina* and *Phleum alpinum* species, whereas the sheep folding applied on a calcium amended grassland showed to have a positive effect on the appearance of *Trifolium repens, Festuca nigrescens, Poa pratensis, Agrostis capillaris* and *Ligusticum mutellina*, which are also the most valuable forage species found in subalpine grasslands. Our results showed that generally fertilization and amendment reduced the share of harmful species in the vegetation cover from approx. 47% to 7 -10%.

The amelioration treatments applied to grasslands seemed to be influencing the appearance of some harmful species such as *Deschampsia caespitosa, Cerastium fontanum* and *Veratrum album*.

The forage quality of the vegetation cover (expressed by the pastoral value) increased with 160 - 200% on the experimental plots fertilized with chemical and organically fertilizers, reaction found especially on the amended plots, compared with plot 11 (control) where the pastoral value was 34.

Following the same pattern, the average green forage mass production for the years 1997 - 1999 was estimated at 2.76 t/ha for the control plot (11) and increased with 175 - 300% on the fertilized plots, especially on plots with sheep folding.

The remaining effect expressed by the improvement factors for the next 9 years (2000 - 2008) - on sets comprising the averages for three years - is presented forward.

The evolution of the pastoral value on plots without amendments (10) decreased by 16% until the period 2006 - 2008 while on amended plots (20) remained almost constant even after 12 years from the application of calcium oxide (Table 3).

**Table 6)** The remaining effect of fertilization and amendments on the pastoral value of the ameliorated *Nardus stricta* subalpine grasslands

| Experimental plot | 1997-1999 | 2000-2002 | 2003-2005 | 2006-2008 | Average | % |
|---|---|---|---|---|---|---|
| 11 | 34.0 | 39.4 | 42.9 | 37.6 | 38.5 | 100 |
| 12 | 56.6 | 49.9 | 47.3 | 43.7 | 49.4 | 128 |
| 13 | 66.6 | 65.6 | 56.7 | 51.1 | 60.0 | 156 |
| **10 years average** | **52.4** | **51.6** | **49.0** | **44.1** | **49.3** | **x** |
| Evoluția (%) → | 100 | 98 | 94 | 84 | x | x |
| 21 | 53.9 | 61.8 | 55.1 | 58.5 | 57.3 | 100 |
| 22 | 65.5 | 66.7 | 57.0 | 62.2 | 62.9 | 110 |
| 23 | 70.0 | 69.9 | 65.6 | 70.0 | 68.9 | 120 |
| **20 years average** | **63.1** | **66.1** | **59.2** | **63.6** | **63.0** | **x** |
| Evolution (%) → | 100 | 105 | 94 | 101 | x | x |
| Difference +,- ; 20 - 10 | + 10.7 | + 14.5 | + 10.2 | + 12.5 | + 13.7 | x |
| **Amendment effects (%)** | **120** | **128** | **121** | **144** | **128** | **x** |

The results recorded during the experimental period showed a constant effect of the amendment, which lead to increases from 20% in the first experimental stage (1997 -1999) up to 44% in the last experimental stage (2006 - 2008), compared to the results recorded on the experimental plots without amendments.

Analyzing the results achieved among the 12 experimental years we observed that the most effective treatment aiming to improve the pastoral value was amendment combined with sheep folding (plot 23) where we found an average PV of almost 70, very good for the natural conditions specific to the subalpine floor. A very similar effect of the treatments was noticed also for green mass production (Table 4).

**Table 7)** The remaining effect of fertilization and amendments on forage green mass production of the ameliorated subalpine grasslands

| **Experimental plot** | **1997-1999** | **2000-2002** | **2003-2005** | **2006-2008** | **Average** | **%** |
|---|---|---|---|---|---|---|
| 11 | 2.76 | 3.63 | 3.89 | 3.82 | 3.52 | 100 |
| 12 | 5.46 | 4.60 | 4.55 | 3.65 | 4.57 | 130 |
| 13 | 8.38 | 8.09 | 5.82 | 5.32 | 6.90 | 196 |
| **10 years average** | **5.53** | **5.44** | **4.75** | **4.26** | **5.00** | **x** |
| Evoluția (%) → | 100 | 98 | 86 | 77 | x | x |
| 21 | 4.82 | 7.44 | 5.15 | 6.83 | 6.06 | 100 |
| 22 | 7.49 | 7.82 | 7.32 | 6.69 | 7.33 | 121 |
| 23 | 8.04 | 8.93 | 8.38 | 8.18 | 8.38 | 138 |
| **20 years average** | **6.78** | **8.06** | **6.95** | **7.23** | **7.26** | **x** |
| Evolution (%) → | 100 | 119 | 103 | 107 | x | x |
| Difference +,- ; 20 - 10 | + 1.25 | + 2.62 | + 2.20 | + 2.97 | + 2.26 | x |
| **Amendment effects (%)** | **123** | **148** | **146** | **170** | **145** | **x** |

A similar reaction of green mass production like that presented for the previous experimental stage was found also on the final experimental period stage. Thus, on the experimental plot without amendments (10) the green mass production decreased with 23% while on the plots amended (20) an increase with 7% was recorded, a fact less highlighted in the scientific literature.

Following the same pattern, we recorded a 12 years average GM higher than 8 t/ha for the amended and sheep folding plots (23), which seemed to be three times higher than the average GM reached on the control plot (11) during the years 1997 - 1999.

A final comparative analysis was made for the potential dairy milk production and for the optimal loading with animals (Table 5).

By applying the formulas presented in the Material and method section – formulas for calculating the grazing capacity and for the evaluation of dairy milk production - the importance of the calcium amendment for correcting soil acidity and the special effect of organic fertilization by sheep folding is highlighted once again.

**Table 8)** The grazing capacity and the dairy milk production recorded on the ameliorated subalpine grasslands Blana-Bucegi 1997- 2008

| Improvement treatments plot | Grazing capacity for 85 days (UL/ha) | Dairy milk production l/ha |
|---|---|---|
| **10. Without calcium amendments** | | |
| 11 – unfertilized plot | 0.64 | 1,970 |
| 12 – fertilized with chemical fertilizers $N_{150}$ $P_{22}$ $K_{42}$ kg/ha, for 3 consecutive years | 0.83 | 2,530 |
| 13 – sheepfold 5 nights/1 sheep/$m^2$ | 1.25 | 3,070 |
| 10 years average | 0.91 | 2,520 |
| **20. With amendments on 2/3 Ah (7,5 t/ha CaO)** | | |
| 21 - unfertilized | 1.10 | 2,940 |
| 22 – fertilized with NPK | 1.33 | 3,220 |
| 23 - sheepfold | 1.52 | 3,530 |
| 20 years average | 1.32 | 3,230 |
| Difference 20-10 +; - | **+ 0.41** | **+ 720** |
| (%) | 145 | 128 |

As demonstrated by our results, the 12 years average for dairy milk production per hectare can be increased from 1,970 to 2,940 liters, which is translated in almost 1.000 liters/year, only by amendments and rational grazing, and thus justifying the economically advantages of these technological measures which expressed a long time effect.

Considering the same experimental period we observed that sheep folding applied on grasslands without amendments enhanced an extra 500 l/ha dairy milk production increase, while for the amended grassland the increase recorded was only with 300 l/ha dairy milk production. Comparing these results with those recorded for the fertilized plots we noticed that the fertilization with NPK seems to be less efficient on a long term basis, requiring a more frequently application of chemical fertilizers.

In the strategy developed for improving these subalpine grasslands with soils with extremely low supply in nutrients, we can cover for the beginning only 15 - 20% of the grassland surface by sheep folding, for the rest of the grassland being necessary to apply chemical fertilizers combined with amendments.

## Conclusions

(1) The subalpine grasslands from Carpathians Mountains showed to be low productive mainly because of soils high acidity, low supply with nutrients and irrational grazing.

(2) The application of calcium amendment and of fertilization with chemical or organically fertilizers through sheep folding, resulted in significant improvements in the vegetation cover of grasslands dominated by *Nardus stricta*, improvement highlighted through the expansion of some valuable forage species like *Agrostis capillaris, Festuca nigrescens, Poa pratensis, Trifolium repens* and others.

(3) The best results were reached on the experimental plots amended on 2/3 Ah (7.5 t/ha CaO), fertilized for 3 consecutive years with $N_{150}$ $P_{22}$ $K_{42}$ kg/ha or with sheep folding for 5 nights/1 sheep/$m^2$, treatments which delivered a loading with animals of 0.8-1.5 UL/ha for 85 grazing days and a 12 years average dairy milk production ranging between 2,500-3,500 l/ha, results translated as being very economic for the subalpine grasslands studied.

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