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Sustainable Management of *Nardus stricta* L. Grasslands in Romania's Carpathians

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Abstract

The grassland area of Romania covers over 4.8 million hectares, of which more than a half are located in upland areas. In the present research it has been studied the influence of organic fertilization on the productivity, vegetal canopy and fodder quality of the intramontane Depression of Vatra Dornei, from the North-Eastern Romanian Carpathians, at rates of 20-50 Mg ha^{-1}, applied either on a yearly basis, or every two years. The purpose of this study is to underline the dynamics of productivity and phytocenosis biodiversity, due to the application of some practical, technical measures meant to improve the production and fodder quality of *Nardus stricta* L. permanent grasslands, with minimal effects on the environment. The organic fertilizer rates triggered changes in the canopy structure by reducing the percentage of *Nardus stricta* L species, from 70% to 14-31%, and increasing the percentage of legumes, as well as the productivity and fodder quality 5-30%, respectively.

Keywords: biodiversity, fertilization, fodder quality, grassland, productivity

Introduction

In Romania, the grassland area, dominated by *Nardus stricta* L.*,* covers 200,000 hectares.

Meadow degradation is determined by changes that take place in plant living conditions and in the structure of vegetation. For a long-term period no elementary management measures were applied on permanent meadows in Romania, estimating that they could get efficient yields without technological inputs. The organic fertilization has a special significance for permanent meadows if their soils show some unfavourable chemical characteristics. The investigations carried out until today have demonstrated the positive effects of reasonably applied manure on grasslands.

Within this context, the main aim of the present study was to improve the productivity of natural grasslands by finding economically efficient solutions that respect their sustainable use and the conservation of biodiversity (Basnou *et al.*, 2009, Bullock *et al.*, 2007, Klavina *et al.*, 2001, Tilman *et al.*, 1996). An important factor in getting a high quality animal production is the quality of fodder, which is determined by its chemical composition. On the other hand, the productivity and fodder quality are influenced by the floristic composition, morphological characteristics of plants, grassland management, vegetation stage at harvest and level of fertilization (Aarssen, 1997; Belanger *et al.*, 2008; Bullock *et al.*, 2007; Dodd *et al.*, 2004; Duru *et al.*, 2010; Gaisler *et al.*, 2004; Hejcman *et al.*, 2010; Magyar *et al.*, 2008; Potsch, 1998; Sivicek *et al.*, 2011; Tilman *et al.*, 1996; Vintu *et al.*, 2008; 2011).

Materials and methods

To accomplish the objectives of these studies it have been conducted a monofactorial experiment in the Cosna region, in four repetitions blocks with 20-sq. meter randomized plots on *Nardus stricta* L. grasslands, situated at an altitude of 840 m, on lithic dystrudepts with 1.36 mg/100 g soil P_{AL} and 38.1 mg/100 g soil K_{AL} (Bakker *et al.*, 2002, Janssens *et al.*, 1998).

The fertilization variants were: V_1-Unfertilized control; V_2-20 Mg ha^{-1}, every year; V_3-30 Mg ha^{-1}, every year; V_4-40 Mg ha^{-1}, every year; V_5-50 Mg ha^{-1}, every year; V_6-20 Mg ha^{-1}, every 2 years; V_7-30 Mg ha^{-1}, every 2 year; V_8-40 Mg ha^{-1}, every 2 years; V_9-50 Mg ha^{-1}, every 2 years.

The forage obtained from these grasslands is mainly used to feed dairy cows. The influence of manure has been analysed, and applied each year or every two years at rates of 20-50 Mg ha^{-1} (Tab. 1). The manure with a content of 0.42% total N, 0.19% P_2O_5 and 0.27% K_2O was applied by hand, early in spring, at the beginning of grass growth. The Kjeldahl method was used for the determination of crude protein, the Weende method for the determination of crude fiber, the photometrical method for the determination of total phosphorus, ash was determined by ignition, whereas the nitrogen nutrition index (NNI) was determined by the method developed by Lemaire *et al.*

Tab. 1. Influence of organic fertilization on the yield of *Nardus stricta* grasslands from the Carpathian Mountains of Romania (Mg ha^{-1} DM)

Manure rate	2009	2010	Average of 2009-2010	
	Mg ha^{-1}	Mg ha^{-1}	Mg ha^{-1}	%
Unfertilized control	1.25	2.30	1.77	100
20 Mg ha^{-1}, every year	2.55*	2.40	2.48	140
30 Mg ha^{-1}, every year	2.34*	4.23**	3.29**	186
40 Mg ha^{-1}, every year	3.59***	4.74***	4.17***	236
50 Mg ha^{-1}, every year	4.73***	6.32***	5.53***	312
20 Mg ha^{-1}, every 2 years	2.28	2.92	2.60	147
30 Mg ha^{-1}, every 2 years	2.59*	3.13	2.86*	162
40 Mg ha^{-1}, every 2 years	1.78	4.14**	2.96*	167
50 Mg ha^{-1}, every 2 years	2.39*	4.28**	3.33**	188
*LSD$_{0.05}$	1.08	1.15	1.02	
**LSD$_{0.01}$	1.49	1.58	1.40	
***LSD$_{0.001}$	2.10	2.17	1.93	

(1989): NNI=100 x N/4,8 x (DM)$^{-0,32}$, where N: plant nitrogen content (%), DM: dry mater production (Mg ha^{-1}). All fodder analyses have been performed on samples taken from the first harvest cycle, based on the average values of the years 2009-2010.

The vegetation was studied using the method Braun-Blanquét. For floristic data were calculated the mean abundance-dominance (ADm). Data regarding the sharwe of economic groups, species number and Shannon Index (SI) were processed by analysis of variance.

For the production yields, statistical analyses were performed using ANOVA, applying the Least Significant Difference (LSD) test.

Results and discussion

The fertilization of mountain grasslands with organic fertilizers leads to an improvement in terms biodiversity, productivity and quality (Ansquer *et al.*, 2009, Schellberg *et al.*, 1999). The use of 20-50 Mg ha^{-1} manure accounted for, alongside the climatic factors, a significant yield increase, especially when applying 30-50 Mg ha^{-1}. At these rates, the DM yield recorded a significant increase, compared with the control variant. Considering the average of the two years, the control variant recorded values of 1.77 Mg ha$^{-1,}$ whereas by fertilization, it has been obtained yields of 3.29-5.53 Mg ha^{-1} DM, at rates of 30-50 Mg ha^{-1}, applied on a yearly basis, and 2.86-3.33 Mg ha^{-1} DM at the same rates, applied once every 2 years, respectively.

The organic fertilization of *Nardus stricta* L. grasslands, with moderate rates of 20-30 Mg ha^{-1} manure, has determined the increase in the CP (crude protein) content by 45.9 g kg^{-1} DM, compared with the unfertilized control variant. The rates of 40-50 Mg ha^{-1} diminished the percentage of dominant species and the increase of CP yield with 246.2-422.8 kg ha^{-1} when manure was added once a year and 189.0-243.2 kg ha^{-1}, when manure was added every 2 years, respectively, in comparison with the control variant. The ash content increased in all fertilized soils, varying between 71.0-83.1 g kg^{-1} DM, compared to merely 61.2 g kg^{-1} DM at the control variant. The crude fiber content (CF) was the highest at the control variant (285.3 g kg^{-1} DM) and the lowest at the variant fertilized with 50 Mg ha^{-1}, applied once every 2 years, of 228.3 g kg^{-1} DM (Bochi-Brum *et al.*, 2011). Phosphorus, an important element in animal nutrition, recorded an increase from 1.4 g kg^{-1}DM at the control to 2.2 g kg^{-1} DM with the use 50 Mg ha^{-1} manure, applied once every 2 years (Tab. 2) (Hejcman *et al.*, 2010). The NNI presented values comprised between 25-53, thus, indicating a deficiency in nitrogen nutrition (Agnusdei *et al.*, 2010).

The organic fertilization on permanent grasslands has resulted in some changes in the canopy structure, both in terms of the number of species as well as in their percentage in the vegetal canopy (Duru *et al.*, 2010; Hejcman *et al.*, 2007; Jancovic *et al.*, 1999; Kirkham *et al.*, 2008; Marini *et al.*, 2007; Oerlemans *et al.*, 2007; Schellberg *et al.*, 1999; Vintu *et al.*, 2008, 2011). Thus, the number of species has increased from 18 at the control variant to 25-31 at fertilization rates, while the percentage of *Nardus stricta* L. species plunged from 70% at the control to 14-33% in the case of the fertilized experiments. Moreover, the legume species increased by 5-28% (Tab. 3).

Species number increased towards the control, for all fertilization variants. Shannon weaver index (SI) was compared to the control with the value between 1.07 and 2.52.

Tab. 2. Influence of organic fertilization on yield (Mg ha^{-1} DM) and NNI and CP quantity (Kg ha^{-1}) and on chemical composition of the fodder obtained from *Nardus stricta* grasslands (g kg^{-1} DM), mean 2009-2010

Manure rate	Mg ha^{-1} DM	CP	Ash	CF	P_{total}	Kg ha^{-1} CP	NNI
Unfertilized control	1.77	62.6	61.2	285.3	1.41	110.8	25
20 Mg ha^{-1}, every year	2.48	88.2***	71.0	264.2	1.92*	218.7	39
30 Mg ha^{-1}, every year	3.29**	108.5***	83.1	270.4	2.05*	357.0	53
40 Mg ha^{-1}, every year	4.17***	97.9***	78.2	258.1	2.13**	408.2	52
50 Mg ha^{-1}, every year	5.53***	96.5***	81.6	253.6	2.04*	533.6	55
20 Mg ha^{-1}, every 2 years	2.60	82.8***	79.0	247.5	1.86*	215.3	37
30 Mg ha^{-1}, every 2 years	2.86*	92.2***	77.5	241.6	2.17*	263.7	43
40 Mg ha^{-1}, every 2 years	2.96*	101.3***	80.7	230.5	1.95*	299.8	48
50 Mg ha^{-1}, every 2 years	3.33**	106.3***	79.2	228.3	2.22**	354.0	52

CP=crude protein, CF=crude fiber, P_{total}= total phosphorus, NNI= nitrogen nutrition index; *=$P \leq 0.05$; **=$P \leq 0.01$; ***=$P \leq 0.001$

Tab. 3. Influence of organic fertilization on the evolution of the vegetal canopy, 2010

Species	Plant ADm[1], degree %								
	V_1	V_2	V_3	V_4	V_5	V_6	V_7	V_8	V_9 [2]
Agrostis capillaris	+	5	3	2	1	+	+	+	5
Anthoxanthum odoratum	-	4	+	-	+	3	6	4	5
Briza media	+	6	6	5	6	8	7	8	10
Cynosurus cristatus	-	-	-	-	-	3	+	-	-
Dactilys glomerata	-	-	-	-	3	-	-	-	-
Festuca pratensis	-	+	10	6	2	-	-	2	-
Festuca rubra	+	1	+	3	3	+	5	5	3
Nardus stricta	70	32	15	14	15	41	32	33	31
Phleum pratense	+	7	2	-	-	-	-	-	2
Grasses	70	55	36	30	30	55	50	52	56
Lotus corniculatus	-	18	13	2	3	5	5	5	+
Trifolium pratense	+	10	5	3	5	3	4	3	5
Trifolium repens	-	+	+	-	+	2	3	2	+
Legumes	0	28	18	5	8	10	12	10	5
Achillea millefolium	+	3	12	35	40	20	9	6	5
Ajuga reptans	+	+	+	+	+	+	+	+	+
Alchemilla xanthochlora	6	2	6	2	6	3	6	3	6
Chrysanthemum leucanthemum	2	3	-	-	-	-	-	-	-
Campanula obietina	-	+	+	+	+	+	+	2	4
Centaurea cyanus	-	-	+	-	-	-	-	-	-
Cerastium semidecandrum	1	+	+	+	+	+	5	3	+
Cruciata glabra	2	2	3	+	3	+	+	3	3
Fragaria vesca	-	-	+	+	+	+	+	+	+
Hyeracium pilosella	3	2	3	+	-	+	-	+	+
Hypericum maculatum	2	+	1	3	2	2	4	6	6
Leucanthemum vulgare	-	-	+	-	-	-	-	-	+
Luzula multiflora	-	-	-	-	-	+	+	-	-
Lychnis flos-cuculi	-	-	+	+	+	+	-	-	-
Prunella vulgaris	+	+	+	+	-	+	+	-	+
Polygala amarella	-	-	-	-	-	-	+	-	-
Polygala vulgaris	-	-	-	-	+	+	-	-	-
Plantago lanceolata	-	-	+	+	3	+	+	2	+
Potentila ternate	5	4	5	+	4	5	-	2	2
Rumex acetosa	-	-	-	-	-	+	-	+	-
Rumex acetosella	-	1	+	-	+	1	+	-	-
Ranunculus acer	1	-	+	2	2	1	+	2	+
Taraxacum officinale	2	0	2	+	+	3	4	4	-
Thymus pulegioides	2	-	2	-	-	+	+	+	-
Tragopogon pratensis	-	+	-	-	-	+	+	-	+
Veronica chamaedrys	1	+	12	+	-	-	10	5	1
Veronica officinalis	1	-	-	23	2	-	-	-	7
Viola tricolor	2	+	+	+	-	+	+	+	5
Forbs	30	17	46	65	62	35	38	38	39
Number of species	18	25	30	25	26	31	28	26	27
Shannon Index (SI)	1.07	2.27*	2.52*	1.93	2.15*	1.96	2.28*	2.50*	2.41*

[1] ADm-mean abundance-dominance; [2] V_1 is control, V_2-V_9 are the manure rates applied; *=$P \leq 0.05$, **=$P \leq 0.1$, ***=$P \leq 0.001$

Conclusions

The fertilization of *Nardus stricta* grasslands with 20-50 Mg ha^{-1} manure influenced the yield increase by 40-212% and brought along important changes in the chemical composition of fodder, improving its quality significantly, by increasing the CP content from 62.6 g kg^{-1} DM (control) to 108.5 (30 Mg ha^{-1} manure, applied once every 2 years); the total phosphorus from 1.41 to 2.22 g kg^{-1} DM and ash from 61.2 to 83.1 g kg^{-1}, and by diminishing the

CF content from 285.3 to 228.3 g kg^{-1} DM, thus increasing fodder digestibility.

The application of 20-50 Mg ha^{-1} manure determined important changes in the flower composition as well, by lowering the percentage of *Nardus stricta* species from 70% to 14-33% and increasing the percentage of legumes (*Lotus corniculatus, Trifolium pratense* and *Trifolium repens*) and forbs.

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