Submontane Grasslands in the Czech Republic: The Interdisciplinary Project „Kamenicky II“

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Many of today´s misuses of land, many of the indications of landscape destabilization and many problems of health and nutrition of farm animals and human beings could be remedied by the restoration and use of the traditional submontane grasslands and pastures (RYCHNOVSKÁ, 1993).

Natural and semi-natural grasslands represent important landscape element in the Bohemian-Moravian Highlands, above all in its •ïárské Vrchy region.This region, which area is about 715 square kilometers, has a polyfunctional character being partly exploited for agriculture (grasslands, pastures) and providing a supply of drinking water. It is also of considerable recreational importance.

The aim of our project which was started in 1992 year as a continuation of the MAB field Project no.91 „Function of Grasslands in a Spring Region – the Kamenièky Project“ is to find out how to exploit efficiently the poor submontane grass stands with respect to the landscape protection.

Study sites and methodology

A field experiment was set up near the village Kamenièky (624 m a.m.s.l., average air temperature 6.5° C, yearly sum of precipitation 760 mm, gleye soil) in the landscape reserve •ïárské vrchy region (Bohemian - Moravian Highlands). The experimental variants include natural (N) and renovated grasslands: renovation either by surface sowing (S) or by ploughing and reseeding (R).

Three levels of mineral fertilizers ($kg.ha^{-1}.year^{-1}$) were used in each variant: *a.* control without fertilizers (NFO, SFO, RFO); *b.* P_{30} K_{60} (NF1, SF1, RF1); *c.* N_{90} P_{30} K_{60} (NF2, SF2, RF2) and d. N_{180} P_{30} K_{60} (NF3, SF3, RF3).

Table 1: **Forage production (dry matter in $t.ha^{-1}$ per year) and effectiveness of mineral fertilizer. Mean values, 1993 - 1998 years**

Grasslands/ Experimental variant	Forage production (three cuttings per year)	Influence of mineral fertil. (in % of control)	Increase of fodder production in kg per 1 kg of NPK	N
Natural				
NFO	4.27	100	-	-
NF1	5.70	133.5	15.9	-
NF2	7.04	164.8	15.4	14.9
NF3	8.41	196.9	15.3	15.0
Renovated by surface sowing				
SFO	3.77	100.0	-	-
SF1	5.04	133.7	14.1	-
SF2	6.52	172.9	15.3	16.4
SF3	7.88	209.0	15.2	15.8
Renovated by ploughing and re-seeding				
RFO	3.33	100.0	-	-
RF1	4.75	142.6	15.8	-
RF2	6.46	194.0	17.3	19.0
RF3	7.60	228.0	15.8	15.8

Table 2: **Changes in number of plant species during 1993 - 1999 years**

Grasslands/ Experimental variant		Monocotyledonous	Dicotyledonous	Leguminous	Total
Natural					
NFO	1992	14	16	3	33
	1995	18	23	4	45
	1999	18	20	6	44
NF1	1992	14	17	2	33
	1995	14	21	4	39
	1999	15	20	4	39
NF2	1992	16	17	2	35
	1995	16	19	2	37
	1999	16	20	2	39
NF3	1992	15	16	1	32
	1995	16	21	2	38
	1999	13	24	1	38
Renovated by ploughing and re-seeding					
RFO	1992	18	28	3	49
	1995	21	27	5	53
	1999	28	32	3	63
RF1	1992	17	26	2	46
	1995	19	28	5	52
	1999	24	27	6	57
RF2	1992	17	24	3	44
	1995	16	23	2	41
	1999	20	23	1	44
RF3	1992	17	22	3	42
	1995	20	18	1	39
	1999	20	22	1	43

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Table 3: **Mass of roots, its distribution in the soil profile and values of shoot/root ratio.**

Grasslands/ Experimental variant	soil layer 0-0.20 m t.ha^{-1}	distribution (in %) 0-0.02m	0.02-0.20m	shoot/rott ration
Natural				
NFO	18.55	41.4	58.6	4.34
NF1	18.24	48.5	51.5	3.20
NF2	17.66	49.2	50.8	2.51
NF3	16.07	53.2	46.8	1.91
Renovated by ploughing and re-seeding				
RFO	19.29	35.6	64.4	5.79
RF1	18.96	39.0	61.0	3.99
RF2	19.29	40.8	59.2	2.99
RF3	14.70	39.1	60.9	1.93

Table 4: **Soil physico-chemical characteristics (mean values, n = 9-21).**

Grasslands/ Experimental variant	Soil moisture (%)	pH H_2O	KCl	CEC meq.100g^{-1}	%C_{ox}	C_{HA}/C_{FA}	N_{tot} mg.kg^{-1}
Natural							
NFO	28.1	5.60	4.11	23.20	3.90	1.35	5000
NF1	27.2	5.65	4.10	24.76	4.30	1.35	5268
NF2	25.4	5.55	3.98	24.05	4.51	1.37	5910
NF3	25.3	5.40	3.92	28.74	4.51	1.22	6570
Renovated by surface sowing							
SFO	27.9	5.70	4.25	24.20	3.95	1.33	5320
SF1	27.0	5.60	4.25	24.55	4.22	1.36	6200
SF2	24.9	5.60	4.15	26.12	4.20	1.40	7050
SF3	24.8	5.55	4.10	27.86	3.90	1.20	6890
Renovated by ploughing and re-seeding							
RFO	*21.6*	*5.50*	*4.74*	*25.04*	*3.24*	*1.14*	*4010*
RF1	20.4	5.50	4.70	26.28	3.29	1.15	4025
RF2	20.6	5.40	4.70	27.08	3.50	1.31	5470
RF3	21.4	5.25	4.65	25.96	3.39	1.16	6110

Table 5: Biological characteristis of grassland soils

Grasslands/ Experimental variant	Microbial biomass (μg C_{bio}.g^{-1})	C_{micr}/C_{org} (%)	Soil respiration (μg C-CO_2.g^{-1}24h^{-1})
Natural			
NFO	1458.3	3.47	27.3
NF1	1800.0	3.17	30.1
NF2	1608.3	3.44	31.0
NF3	1683.1	3.05	30.3
Renovated by surface sowing			
SFO	1416.6	3.09	29.2
SF1	1325.0	2.81	30.3
SF2	1508.3	3.56	31.7
SF3	1650.0	2.90	30.2
Renovated by ploughing and re-seeding			
RFO	1383.0	2.63	29.5
RF1	1200.0	3.15	29.0
RF2	1433.3	3.57	34.0
RF3	1415.0	3.86	32.5

Forage production, plant species diversity, mass and distribution of roots and physico-chemical (moisture, pH, CEC, nutrients, humus and its quality) as well as biological soil characteristics (microbial biomass, soil respiration, mobilization of mineral nitrogen, diversity of bacterial DANN, and species diversity of soil mesofauna) are followed using methods described by RYCHNOVSKÁ (1987, 1993), TORSVIK et al. (1990), TESAROVÁ (1997).

Results and Discussion

Data on average production of forage for six years are given in *Table 1*. Production potential of natural non-fertilized submontaineous grasslands at three-times cutting is relatively high (4.27 t.ha^{-1}.year^{-1}). Above-ground biomass production of non-cutted grasslands reaches 1-2 t.ha^{-1}.year^{-1} in the region (JAKRLOVÁ,1993).

After renovation of the stand only by surface sowing or by ploughing and re-seeding, forage production decreased by about 0.5 - 1.0 t.ha^{-1}. PK fertilizers increased the forage production by 40 per cent, N_{90} P_{30} K_{60} by 80 per cent and N_{180} P_{30} K_{60} by 110 per cent (Table 1). The influence of mineral fertilizers was the most effective in grasslands renovated by ploughing and re-seeding in comparison with natural and surface sowing ones.

The production efficiency of mineral fertilizers can be expressed as increament in dry matter production per 1 kg of NPK or 1 kg of N applied (Table 1). If the energy budget is considered (i.e., if the amount of energy required for the production of 1 kg of nitrogen (about 80 MJ) is compared with the amount of energy in the forage consumed by cattle (1 kg of dry fodder = 5.23 MJ) then the

Table 6: **Intensity of ammonification and nitrification expressed as diference between N-NH_4^+ /N-NO_3 content before and after 30 days incubation of soil samples. Data in mg of mineral nitrogen per kg^{-1} of dry soil. Mean values, n = 7.**

Grasslands/ Experimental variant	N-NH_4^+	N-NO_3^-
Natural		
NFO	+14.0	+10.2
NF1	+15.7	+10.8
NF2	+19.2	+12.6
NF3	+26.2	+14.6
Renovated by ploughing and re-seeding		
RFO	+10.1	+7.5
RF1	+11.6	+9.0
RF2	+21.4	+15.8
RF3	+28.9	+18.3

Table 7: Abundance (number of individuals per 100 cm²) and species diversity of soil meso-fauna. A. Oribatida, B. Collembola.

Species	Grassland/Exper.variant			
	NFO	NF3	RFO	RF3
A.Oribatida				
Scheloribates laevigatus (C.L.KOCH, 1836)	26	18	26	41
Podoribates gratus (SELLNICK, 1921)	1	-	-	-
Platynothrus peltifer (C.L.KOCH, 1839)	-	5	-	-
Malaconothrus gracilis HAMMEN, 1952	-	5	1	-
Tectocepheus velatus (MICHAEL, 1880)	-	-	1	-
Hermannia gibba (C.L.KOCH, 1839)	-	-	1	-
Galumna elimata (C.L.KOCH, 1841)	-	-	1	-
Trichoribates trimaculatus (C.L.KOCH, 1836)	-	-	1	3
Oppiella falcata (PAOLI, 1908)	-	-	-	1
B. COLLEMBOLA				
Isotmurus palustris (MÛLLER, 1776)	20	53	30	49
Brachystomella parvula (SCHÄFFER, 1896)	6	-	10	-
Mesaphorura krausbaueri (BÖRNER, 1901)	1	-	2	1
Mesaphorura renuisensillata (RUSEK, 1974)	-	2	-	-
Lepidocyrtus cyaneus (TULLBERG, 1871)	-	-	3	2
Friesea truncata (CASSAGNAU, 1958) -	-	2	-	
Protaphorura armata (TULLBERG, 1869)	-	-	2	-

application of N to grasslands will be economically profitable if dry forage increament exceeds 15 kg. Thus, an economically reasonable grassland production was attained under the studied conditions by applying 90kg N as well as 180 kg N per hectare and year; the lower doses (i.e., 90 kg N) were more effective, however (*Table 1*).

Grass stands comprise population of about 60 species of vascular plants (*Table 2*). No weeds and alien species were found out in natural stands at the beginning. Since 1995 only one weed occured in fertilized variants now and then. *Epilobium ciliatum* invaded fertilized plots first, in the year 1999 it has been recorded in all variants. Relatively high numbers of species in the stands, consisting originally of five sown species, resulted from the soil seedbank and newcomers from adjacent natural stands.

Fertilization decreased the species number in both studied types of stands. It was caused either by intolerance of some species to higher amount of nitrogen (*Fabaceae*) or by strong competition of species (especially grasses) being able to use nitrogen in their favour and to shade other species.

Dry matter of roots (up to the soil depth of 0.2 m) decreases with increasing doses of mineral fertilizer. Simultaneously, roots befome accumulate in the upper 2 cm of soil layers (Table 3). Shoot/root ratios achieve in average higher values in renovated grasslands (3.7) than in natural ones (2.9). Mineral fertilizers show the same effect on their values in both types of grasslands: higher doses are followed by decreasing shoot/root ratios (*Table 3*).

The changes in soil quality of studied grasslands were analyzed, too. As usual, the application of higher doses of mineral fertilizers was followed by an decrease of pH values; simultan-eously, the values of CEC and those of C/N ratio slightly increased (*Table 4*).

Humus content and quality were in average lower in the soil of grasslands renovated by ploughing and re-seeding in comparison with natural and surface sowing ones (*Table 4*). The aeration of the soil subsequent to the stand´s renovation by ploughing resulted in decreased soil moisture (*Table 4*) and an increased soil temperature. This favourably affected the ability of soil microflora to decompose organic substances (see data on soil respiration in *Table 4*). Besides this, the amount of above-ground plant litter entering the decomposition food chain in grasslands renovated by ploughing will be probably lower with respect to the lower plant matter production (*Table 1*).

Values of soil microbial biomass and its participation on soil organic carbon (C_{micr}/C_{org}) are higher in renovated grasslands than in natural ones (Table 5). It indicates the more important participation of soil microflora in matter cycling in renovated grasslands .

There is a substantial difference in the ability of soil microbes to mobilize mineral nitrogen among grasslands studied. Higher intensity of ammonification and above all of nitrification were estimated in the soils of fertilized grasslands renovated by ploughing and re-seeding (RF2, RF3) than in the corresponding variants of natural grasslands (i.e., NF2, NF3) – *Table 6*. This fact together with lower plant production implies the possible leaching of mineral nitrogen from the soils of renovated grasslands RF2 and RF3.

The analyses of bacterial DNA using the reassociation of denaturated bacterial DNA (TORSVIK et al. 1990) enable to characterize the diversity of soil bacterial communities. The grassland soils studied comprise 2,200 to 3,000 of genetically different bacteria; the lowest diversity of bacterial DNA was estimated in the soils of variants NF3 and RF3 (2,350 and 2,200, respectively), i.e., in grass stands fertilized by high doses of mineral fertilizer.

The soils of studied grasslands are characterized by relatively low abundance and number of species of Oribatida and Collembola (*Table 7*). It seems, that renovation of the stand positively influences the community of Collembola. Mineral fertilization desreased the abundance and species diversity of both studied groups of soil mesofauna in natural as well as in renovated grasslands.

Conclusions

The results obtained during 1992-1998 years have proved that production potential of natural submontaineous grasslands is about 4 t.ha^{-1}.year^{-1}. Proper management, i.e., three-times cutting and mineral fertilizers in doses N_{90} P_{30} K_{60} kg.ha^{-1}.year^{-1} increases the forage production of natural and renovated grasslands to about 7-8 t.ha^{-1} . year^{-1}, improves the soil quality and maintains the biodiversity. Higher doses of mineral fertilizer are unrational both from economical and ecological point of view.

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