SOME ECOLOGICAL ASPECTS OF SEMI-NATURAL AND TEMPORARY GRASSLANDS

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ABSTRACT

Some ecological aspects were studied in semi-natural and temporary grasslands at different levels of fertilizer application. The research was carried out in the upland region of central Slovakia at the altitude of 460 m in Banská Bystrica. At zero fertilizer application, soil CO_2 production and C_{ox} content were higher in the temporary grassland. Atmospheric N fixation was also higher in the temporary grassland. However, root accumulation, microbial biomass content and R : S ratio were lower in the temporary grassland. By comparison with the semi-natural grassland, leaf area index (LAI), net assimilation rate (NAR) and crop growth rate (CGR) were higher in the temporary sward. Mean number of grasshoppers was 325 pc/10 m^2 in the semi-natural grassland. The number rose with higher N rates applied. Fixation of N_2, amount of microbial biomass and R : S ratio decreased at fertilizer application in both the grassland types. On the other hand, root accumulation increased.

KEYWORDS

Grassland type, soil microbiology, root, leaf area, photosynthesis, grasshoppers

INTRODUCTION

Ecological studies of grassland have mostly focused on sward analysis without considering the impact of human activities (Innis et al., 1978; Coupland, 1979). Our earlier research concentrated on some functions of grassland under different management (Krajcovic et al., 1980) including microbiological aspects of soil subsystem (Ondrásek, 1995), production process analysis (Gáborcík, 1988) and root accumulation (Gáborcík, 1989). Recently, some aspects of temporary and semi-natural grasslands have been compared under identical ecological conditions and at the same time (Rychnovská, 1990; Tesarová, 1980; Úlehlová, 1990). The objective of this study was a comparison between two types of grassland under different management practices.

MATERIALS AND METHODS

In 1991, a field trial was established at the semi-natural grassland site in Banská Bystrica, central Slovakia, at the altitude of 460 m (α= 48° 44'; Γ= 19° 09') After ploughing in the autumn 1990, the second sward was established consisting of grass/clover mixture with these components and seed rates (kg ha^{-1}): *Dactylis glomerata* L. cv. Rela (4.0), *Festulolium*, intergeneric hybrid, cv. Felina (12.0), *Lolium perenne* L., cv. Metropol (8.0), *Trifolium pratense*, cv. Sigord (3.0) and *Trifolum repens*, cv. Huia (2.0). Both the swards were utilized by 3 cuts at the following fertilizer application:

Treatment	kg ha^{-1}		
	N	P	K
N_0	-	-	-
PK	-	30	60
N_{90}	3 x 30	30	60
N_{180}	3 x 60	30	60

The first rates of N plus P and K were applied in the spring, plus two more N rates after the 1st and 2nd cuts.

Between 1991-1995, the following parameters were studied: a) soil subsystem - biological activity of soil measured by production of CO_2 released from soil (Marendiak and Rehorková, 1970). During the growing period, soil samples were manually taken by an auger (ø 50 mm) from the depth of 0 - 120 mm. In the treated samples, CO_2 release was measured by gas chromatography (Chrom-5; Laboratorní prístroje; Praha). Total microbial biomass content was also determined in the soil samples (Ruzek, 1992). Immediately before sampling, grassland ecosystem ability of N_2 fixation was analyzed using a method of acetylene reduction. The soil samples were taken by a steel cylinder (ø 27 m, 100 mm long), and the above-ground plant parts were cut off up to 20 mm of the soil depth. After incubating the soil samples under controlled conditions (24 hours, 20 °C), reduction activity of nitrogenase of acetylene was determined (Simek, Varela and Úlehlová, 1987). The content of acetylene was measured by gas chromatography (Chrom - 4; Laboratorní prístroje; Praha).

Quantity of accumulated roots was assessed in samples taken manually by an auger (ø 50 mm) from the depth of 0-120 mm (20 replications) after the cuts. The amount of roots was determined after they had been rinsed by warm water and dried at 60°C. In the samples, weight of dry matter (DM) was also determined, namely that of the so called "zone of tillering" (crowns) which comprises litter and bases of grass stems and culms (Gáborcík, 1992).

b) above-ground subsystem: Over the growing period, plant samples were taken from plots of 250 x 250 mm (4 replications) to analyze DM weight and leaf area (LI - 3000, LI - COR, USA). The method of plant analysis (Gáborèík, 1988) was used to calculate net assimilation rate (NAR = g m^{-2}d^{-1}), leaf area index (LAI = m^2 m^{-2}), relative growth rate (RGR = g g^{-1} d^{-1}), relative area growth rate (RGR_A = m^2 m^{-2} d^{-1}) and crop growth rate (CGR = g m^{-2} d^{-1}). Over two years (1991 and 1993), abundance of grasshoppers (Acrididae) was investigated in the semi-natural grassland using a standard method of sampling and calculation by Suslík (1986). Technical problems connected with the sampling made this research impossible in the established grassland.

RESULTS AND DISCUSSION

A comparison of mean values recorded in the sward with zero nutrient application showed that CO_2 production from temporary grassland had been higher by 20% than in the semi - natural grassland and C_{ox} content in soil had been 11% higher. On the other hand, the established grassland was characterized by lower amount of total microbial mass in soil but no differences in N_{tot} of soil were found. Fixation of N_2 was higher by 0.86 kg N m^{-2} in the established sward than in the semi-natural grassland (Table 1). Similar differences were indicated by comparing mean values of all the treatments when soil CO_2 production and C_{ox} content in soil were higher in the established grassland, and total microbial mass content was higher in the semi-natural grassland. Effects of increasing N rates on the parameters and processes studied were not quite explicit. However, there was a significant depressive effect of mineral nutrient application on CO_2 production from soil, on the amount of microbial biomass and on fixation of atmospheric N_2 by sward. A comparison between the root systems of the semi-natural and the established grassland indicated a more intensive accumulation in the semi-natural grassland (Table 2). In the N_o treatment, more intensive root accumulation was found in the semi-natural (0.85 kg m^{-2}) than in the established grassland (0.67 kg m^{-2}). The data averaged over all the treatments confirmed this tendency since the root accumulation was 0.958 kg.m^{-2} in the semi-natural grassland and only 0.798 kg m^{-2} (84%) in the established sward. The application of nutrients affected an increase in root accumulation in all the research treatments. There was a similar rise observed in DM content allocated to crowns but there was a non-significant difference in this parameter (7%) in both the grassland types. The root: shoot ratio (R : S) indicating DM distribution between the above - and below - ground sward parts was higher in the semi - natural (5.66) than in the established grassland (5.15) at the No treatment. There was an explicit decrease in R : S ratio at fertilizer application. An analysis of DM allocation among the above-ground parts of sward, crowns and roots showed that the highest amount of DM was distributed to roots and crowns and the lowest proportion was allocated to the above-ground plant parts. A comparison between LAI and NAR revealed a rise in LAI by 18% and an increase in NAR by 32% in temporary grassland at No treatments (Table 3). The data averaged over all the treatments showed the evidently higher NAR (38%) than the increase in LAI (10%) resulting from the new sward establishment. No differences in RGR and RGR_A were found between the two studied grassland types. The higher LAI and NAR of the established sward influenced also the increase in CGR which was 25% higher than in the semi - natural grassland.

As illustrated by average data on abundance of grasshoppers in 1991 and 1993 (Table 4), their incidence in the sward fluctuated during the growing period and was also influenced by the applied nutrient rates. The highest number of grasshoppers per area unit (10 m^2) was recorded in the middle of the growing season (August). In the mean of all the treatments, the number was 648.2 grasshoppers per 10 m^2. A comparison of the grasshoppers abundance in the individual treatments showed their relatively rising incidence at high rates of N (and also P + K). The relative increase in the incidence of grasshoppers was higher at both the N rates (N_{90} and N_{180}) than at P and K fertilizer application (38% and 49% vs. 21%). The higher incidence of grasshoppers corresponded with the increase in consumption of herbage over the season that rose from 489.0 g m^{-2} in the No treatment up to 755.2 g m^{-2} at the maximum N rate (N_{180}). A part of the herbage consumed by grasshoppers returned to the grassland ecosystem as excreta and these represented 56% of herbage consumption. Similarly to the herbage consumption, the production of excreta increased with the higher nutrient rate application. Over the first three years, the recorded data on functions of the original and the transformed sward indicated differences in production and accumulation of organic matter as well as in some parameters of nitrogen metabolism. A comparative study between the grassland with dominance of *Nardus stricta* L. and renovated grassland (Rychnovská, 1990) pointed out changes in water relations of plants and sward when the renovated sward had higher water consumption and was also more sensitive to water deficiency. It showed that better ability of the established temporary grassland to accumulate DM (Table 3) had been reflected also in the other parts of the carbon cycle. In accordance with the data reported by Tesarová (1990), production of CO_2 from soil increased in the renovated sward, but for C_{ox} in soil just the opposite conclusions were achieved indicating a possibility of different soil properties. Better photosynthetic activity of the temporary sward was not mirrored by an increase in root accumulation and this fact confirmed higher retention capacity of above-ground plant parts. However, a similar comparative study of two grassland types by Ulehlová (1990) had reported results different from our data, namely higher root accumulation in the renovated sward. In agreement with these data, we confirmed a positive effect of N on root accumulation even though our earlier results had indicated negative effects of N (Gáborcík, 1985). The introduction of clovers into the renovated grassland had positive impact on the ability of the atmospheric N fixation by the sward, especially at zero fertilizer application. On the other hand, the input of mineral N in the fertilizer showed negative effects on N_2 fixation, as recorded by Rao (1976). Neither the fertilizer application nor the transformation of the sward by renovation affected the content of N_{tot} in soil and this had also been confirmed earlier by Ulehlová (1990). The earlier research on the incidence of grasshoppers in grassland had not comprised studies of the impact of human activities (Suslík, 1986), nor a model of their abundance in the grassland ecosystem (Rodell, 1987) but had included an influence of the N application. The observations indicated some parts of N and C cycle in grassland where grasshoppers participated as the consumers of plant biomass. From the viewpoint of the effect of applied nutrients, there was an interesting fact observed. The grasshoppers preferred the swards with higher N rates applied which might indicate a link to changes in chemical composition of herbage (Sanjayan and Ananthakrishnan, 1987). Under the conditions of high application rates, the content of N and also of chlorophyll was higher (Gáborcík, 1988).

The research on explanation of changes in the studied processes is being continued in both the grassland types, including reseeded grassland. The research data might specify some parts of the C and N cycle in grassland ecosystem over a longer period of time.

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Table 1

Mean soil CO_2 production, content of total microbiological biomass, soil carbon (C_{ox}) and nitrogen (N_{tot}) a fixation of N_2 in temporary (TG) and permanent grassland (PG)

Index	Type of grassland	Treatment N_0	PK	N_{90}	N_{180}	Mean
Soil CO_2 production ($mg\ kg^{-1}\ 14\ d^{-1}$)	PG	585.0	634.8	501.3	572.5	573.40
	TG	703.8	698.4	695.9	556.1	663.55
Microbiological bimass ($mg\ kg^{-1}$)	PG	1680.7	1664.1	1602.8	1482.4	1607.50
	TG	1285.2	1200.8	1049.6	1283.0	1204.65
C_{ox} ($g\ kg^{-1}$)	PG	30.46	32.97	30.52	33.35	31.83
	TG	33.82	35.03	35.17	32.99	34.25
N_t ($g\ kg^{-1}$)	PG	2.60	2.87	2.62	2.76	2.71
	TG	2.59	2.73	2.61	2.58	2.63
FIXATION of N_2 ($g\ m^{-2}$)	PG	4.15	4.15	2.52	-	3.61
	TG	5.01	3.98	2.41	-	3.80

Table 2

Distribution of dry matter in permanent (PG) and temporary grassland (TG)

Treat-ment	Type of grassland	Dry matter weight ($kg\ m^{-2}$) Root	Tillering zone	Above-ground	Total	Proportion (%) Root	Tillering zone	Above-ground	R:S Ratio
N_0	PG	0.85	0.54	0.15	1.54	55.39	35.16	9.45	5.67
	TG	0.67	0.48	0.13	1.28	52.43	37.58	9.99	5.13
PK	PG	0.95	0.58	0.14	1.67	56.69	34.60	8.44	6.79
	TG	0.84	0.55	0.17	1.56	53.62	35.55	10.82	4.94
N_{90}	PG	0.94	0.69	0.22	1.85	50.68	37.54	11.79	4.27
	TG	0.76	0.66	0.23	1.64	45.93	39.88	14.20	3.30
N_{180}	PG	1.08	0.71	0.25	2.04	53.01	34.64	12.35	4.32
	TG	0.92	0.65	0.26	1.84	50.30	35.36	14.33	3.54

Table 3

Principal growth parameters of permanent (PG) and temporary (TG) grassland

Treatment	Type of grassland	Parameter LAI ($m^2\ m^{-2}$)	NAR ($g\ m^{-2}\ d^{-1}$)	RGR ($g\ g^{-1}\ d^{-1}$)	RGRA ($m^2\ m^{-2}\ d^{-1}$)	CGR ($g\ m^{-2}\ d^{-1}$)
N_0	PG	1.65	0.92	0.02	0.02	1.38
	TP	1.96	1.67	0.03	0.04	2.70
PK	PG	2.03	0.71	0.02	0.02	1.17
	TG	2.28	1.16	0.04	0.02	0.55
N_{90}	PG	2.38	1.01	0.02	0.03	1.94
	TG	2.76	1.47	0.03	0.03	3.23
N_{180}	PG	2.67	0.93	0.02	0.02	1.64
	TG	2.57	0.62	0.02	0.02	1.20
Mean	PG	2.18	0.89	0.02	0.03	1.53
	TG	2.39	1.23	0.03	0.03	1.92

Table 4

Abundance of grasshopers, phytoconsumption and faeces production in permanent grassland

Treatment	Abundance (No 10 m^{-2} month) May	June	July	August	September	October	Mean	Phyto-consumption ($kg\ ha^{-1}$)	Faeces production ($kg\ ha^{-1}$)
0	62.9	192.1	371.7	490.6	482.5	351.3	325.2	489.0	273.8
PK	67.3	230.8	409.4	621.5	551.3	480.8	393.5	599.6	335.8
N_{90}	42.5	291.7	492.9	717.7	643.5	503.8	448.7	683.2	382.6
N_{180}	39.5	226.0	535.2	763.1	781.3	553.3	483.1	755.2	423.9