Effect of fertilization renovation on the production capacity of permanent grassland

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ABSTRACT

From the experimental study of fertilization renovation (after its three-year absence) on production capacity of semi-natural grassland in the area of Strážov Hills (Middle Slovakia, height above see level 640 m, association *Lolio-Cynosuretum* Tx. 1937, time of experiment 1997–1999) it follows that yearly application of doses 60–120 kg N(+PK)/ha leads to a rapid renovation of production feat at high yield stability and production effects by infused nutriens (increase of yield 15.3 or 13.6 kg dry matter/kg NPK, 23.1 or 19.1 kg dry matter/kg N). Within the dose interval 120–240 kg N(+PK)/ha, the values of average production 1 kg N (8.64 kg dry matter) fall to almost one half in comparison to the interval 60–120 kg N(+PK)/ha, and when compared to the dose interval 0–60 kg N(+PK)/ha, they fall to almost one third. When alternating applications of nutrients in particular years (PK-NPK-PK, PK-0-PK, N_{60}PK-N_{120}PK-N_{240}PK) the yield variation in time (V_x = 25.56–43.64%) increases enormously in comparison to habitual application of the same nutrient doses (V_x = 5.26–10.42%).

Keywords: alternating fertilization; nitrogen; aboveground phytomass production; fertilization renovation

Gradation of mineral fertilizer rates, mainly nitrogen, expressively influences the grassland production ability (Klapp 1971). The Velich's results (1986) prove that under favourable moisture conditions and sufficient phosphorus, potassium and other macro- and microelement nutrition, by nitrogen fertilization application we can approach the ecological conditioned border of potential fertility and yields can be increased by 100–200%.

The issue of optimal nutrition is complex because semi-natural grassland is very diversified and initial grassland state is very important for fertilization effect (Klapp 1971, Lichner et al. 1977, Martens et al. 1998). The optimal nutrient amount is different for each grassland type and combination of stand conditions (Klimeš 1990).

After a long-term application of higher nutrient rates, not only positive consequences of intensive fertilization, but also negative phenomena were found out-botanical composition changes and consequently the yield decreased. Krajčovič et al. (1968) state that changes in botanical composition are also reflected in fertilization efficiency which after the first years of nutrient application increases up to the maximum in the 4th–6th year, then as a result of degradation phenomena decreases and the differences among various stands are eliminated. Jančovič (1999) claims that high nitrogen rates have a degradation effect on the botanical composition and stand soil properties, therefore, they negatively influence the environment.

Mineral fertilization cessation in grassland is considered to be a specific problem. According to Jančovič and Vozár (1999), the productivity development, quality and botanical composition of grass phytocenosis are negatively influenced by fertilization absence. This development can be suppressed and grassland can be revitalized by fertilization renovation and regular exploitation.

Lolio-Cynosuretum typicum R. Tx. 1937 an association is formed by extremely grazed communities of lowland grasslands and alluvial leas up to the submontane degree with a characteristic grass *Lolium perenne* L. association which on soils with higher gravel content succumbs to composition of such species as *Festuca rubra* L. and *Agrostis capillaris* L. by which it is gradually replaced (Jančovič 1999).

MATERIAL AND METHODS

Experimental investigations were carried out on a long-term grassland trial. In the years 1986–1993, there was realized nutrition of different intensity. There was an intentional fertilization cessation in the period from 1994–1996 and only one cut was carried out in the period of maximum aboveground

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Table 1. Agrochemical soil properties of original site (1986)

Depth (mm)	pH/KCl	Available nutrients (mg/kg)				N_{tot} (g/kg)	C_{ox} (g/kg)
		P	K	Mg	Ca		
0–100	4.6	15.7	120.0	113.7	850	4.0	36
101–200	4.6	4.3	66.0	91.9	750	2.8	24

phytomass production (Rychnovská et al. 1987). In the submitted work, there are the results of observations after fertilization renovation and exploitation over a period of years 1997–1999.

The site is situated at the altitude of 640 m a.s.l. in the locality Chvojnica on the mountain of The Strážov Hills (48°53′N, 18°33′E). It belongs climatically to a mildly temperate region, semi region mildly dry and a prevailing cold winter. According to long-year measurements, the average yearly temperature is 7.5°C, within growing season 11.1°C. Long-term average of whole year sum of precipitation represents 848 mm and that of growing season 431 mm. Soil-forming substrate is formed by crystalic rocks with predominance of granite and crystalic slates on which the brown, acidic, sandy-loam soil (Cambisol) has developed. Agrochemical soil properties of original site are stated in Table 1.

Before establishment of experiments from phytocenological aspect, the original grassland represents *Lolio-Cynosuretum* Tx. 1937 association. From the viewpoint of botanical species occurrence, grass species (73%) prevailed in the grassland; leguminous plants formed a 2% portion and other meadow herbs a 25% portion.

The trial was originally established by a block method in four replications with the area of an experimental plot 10 m^2 and protective 0.5 m wide belt. Nutrient application and dosing are stated in Table 2.

Grasslands were exploited by three cuts:
1st cut – at the beginning of dominant grass earing
2nd cut – for to 5–6 weeks after the 1st cut
3rd cut – 8 weeks after the 2nd cut

Dry matter yields were evaluated by Klimeš et al. (2004).

RESULTS AND DISCUSSION

Botanical composition and its changes were after exploitation renovation influenced mainly by fertilization. By graduated nitrogen fertilization intensity, the portion of botanical grass species was increased (in particular *Festuca rubra* L.). These were spread in the grassland to the detriment of leguminous plants and other meadow herbs. The regular PK-fertilization supported mainly leguminous plants whose dominance was increased in the last investigated year (1999) up to 49%. The

Table 2. Nitrogen dosing in the year of fertilization (kgN/ha)

Series	Variant	1997	1998	1999
	1	–	–	–
	2	PK	PK	PK
A	3	PK + 60 N	PK + 60 N	PK + 60 N
	4	PK + 120 N	PK + 120 N	PK + 120 N
	5	PK + 240 N	PK + 240 N	PK + 240 N
	6	PK	PK + 60 N	PK
	7	PK	PK + 120 N	PK
B	8	PK	PK + 240 N	PK
	9	PK	–	PK
	10	PK + 60 N	PK + 120 N	PK + 240 N

Nutrients in amount P = 35 kg/ha and K = 70 kg/ha, as well as the first N-rate were applied once in spring, in time when grassland greened; the other N-rates were applied 10 days after a cut at the latest; phosphorus was applied in the form of granulated superphosphate (8% P), potassium in the form of potash salt (41.5% K) and nitrogen in the form of nitrate of ammonia with limestone (27.5% N); in autumn 1996 was applied 2 t/ha $CaCO_3$

Table 3. Primary production of verified growth (x in t dry matter/ha) accompanied by the basic statistics characteristic

Year (t)	Variant									
	1 (C)	2	3	4	5	6	7	8	9	10
1997 (1)	0.977	1.504	3.037	3.829	4.983	1.815	1.832	2.107	2.183	2.674
1998 (2)	0.980	1.665	3.608	3.747	5.241	2.930	4.132	4.336	1.037	3.622
1999 (3)	0.917	1.806	3.56	4.257	4.718	2.085	2.340	2.779	1.428	4.639
$\bar{x}$	0.958	1.658	3.042	3.944	4.981	2.277	2.768	3.074	1.549	3.645
%:C	100	173.10	355.08	411.72	519.90	213.76	288.93	320.88	161.72	380.48
HG ($P_{0.05}$)	a	ab	cd	cd	e	b	c	dc	ab	cd
HG ($P_{0.01}$)	a	ab	c	c	e	b	c	c	ab	c
S_x	0.036	0.151	0.317	0.274	0.262	0.582	1.208	1.143	0.583	0.983
V_x (%)	3.76	9.11	10.42	6.95	5.26	25.56	43.64	37.18	37.64	26.97
$i(t_2/t_1)$	100.31	110.70	108.80	97.86	105.18	161.43	225.55	205.79	47.50	135.45
$i(t_3/t_1)$	93.86	120.08	117.22	111.18	94.68	114.88	127.73	131.89	65.41	173.49
$i(t_3/t_2)$	93.57	108.47	98.67	113.61	90.02	71.16	56.63	64.09	137.70	128.08

t = years, C = control variant, HG = homogenous groups on the level of statistic importance $P_{0.01}$ and $P_{0.05}$, S_x = authoritative deviation, V_x (%) = variant coefficient, $i(t_2/t_1)$ and $i(t_3/t_1)$ = individual basic indices, $i(t_3/t_2)$ = individual chain indices

increase of leguminous plant portion in comparison with unfertilized grassland was found out in the dose 60 kgN/ha.

The alternating PK and NPK-nutrition provided such vitality of leguminous plants that in the year with a nitrogen fertilization they did not disappear from the grassland and even, they increased their occurrence in the following year. In the variant with alternating of PK-nutrition and 60 kg N(+PK)/ha, the progressive leguminous plant development was found out also in the year with a nitrogen application.

The dry matter yield of the aboveground phytomass in the investigated period is presented in Table 3.

Unfertilized grassland (variant 1) was characteristic by a very slight dry matter yield (0.917–0.980 t/ha). The causes of low yield ability of original grassland can be seen mainly in agrochemical soil properties (Table 1), on the basis of which the grassland from less productive species with a slight leguminous plant portion was formed. This tendency was even intensified by a regular three-cut exploitation and nutrition uptake without their supplement. The dry matter yield was expressively influenced by nutrition (Table 4). The experimental year had a significant influence (Table 4).

PK-fertilization (variant 2) was manifested by a yield increase in comparison with an unfertilized control in all the year round yields.

The nitrogen fertilization increased the dry matter yield in all particular years and it also influenced the final production within the investigated period. There are unambiguously higher dry matter yields in N-fertilized variants in comparison with variants with N-absence. Anyway, the classical model of yield increase on grasslands was confirmed, the model published in many works dealing with grassland nutrition (Velich 1986, Holúbek 1991 and others). It is interesting that even in the first year after fertili-

Table 4. Variance analysis of primary production results of verified grassland in different nutrition

Source of variability	*df*	*mS*	*F*	*P*-level
Variants (A)	9	18.691	78.205**	0.0000
Years (B)	2	4.110	17.197**	0.0000
Interaction A × B	18	1.594	6.669**	0.0000
Repetition	3	0.609	2.548	0.0646
Residual	87	0.239	–	–
Total	119		–	–

Table 5. Production efficiency of applied nutrients (kg dry matter/kg NPK)

Year	Variant								
	2	3	4	5	6	7	8	9	10
1997	5.27	12.87	12.96	11.78	8.38	8.55	10.13	12.06	10.61
1998	6.85	16.42	12.57	12.53	12.19	14.33	9.87	–	12.01
1999	8.89	16.52	15.18	11.18	11.68	14.23	18.62	5.11	10.95
Average	7.00	15.27	13.57	11.83	10.99	12.93	11.75	8.87	11.19

zation renovation (1997), the dry matter yield was increased to the level which was then maintained within the whole investigated period.

The aim of the trial was to investigate the influence of increased nutrient rates, usefulness of annual nitrogen fertilization for the achievement of particular production levels, eventually the possibility of periodical nitrogen fertilization absence with the intention to utilize its possible residual effects for the maintenance of the same average yield. The variants 6–8 were used for the achievement of this aim.

The nitrogen application in the second investigated year (Table 3) caused the dry matter yield increase to the yield level of grasslands annually fertilized by N (variants 3–5 and variant 10). In the following year (with PK-application only), the dry matter yield was decreased, but it was higher than on the variant 2, what confirms the hypothesis about the residual nitrogen effect (Jančovič 1999).

However, if the three-year results in the dry matter yield are compared, these are unfavourable for grasslands with N-nutrition cessation because in all cases the lower dry matter yield was recorded. The cause is not only in the low yield in an initial year, but also in the slight residual N-effect, and then in an expressive yield decrease in the third investigated year (Table 3).

Jančovič (1999) in a methodologically similar trial found out that by PK-fertilization alternating with a periodical two-year application of nitrogen fertilization in a four-year cycle, there were not achieved significantly lower yields than in an annual application 120 kg/ha.

One of the alternatives of average N-rate decrease was chosen its gradation in investigated years on the variant 10. Besides the average N-rate decrease, the aim of the trial was also gradual adaptation of botanical composition to the increase of N-nutrition level and ability of higher nutrient rate uptake. Lichner et al. (1977) prove that changes of botanical composition are after fertilization realized gradually. The species with average nutrient requirements are spread on the grassland at the beginning of fertilization. In another fertilization phase, these species are suppressed by species with higher nutrient requirements.

The results achieved in particular years corresponded with yields of grasslands fertilized annually by the rate which was identical with the rate in a particular year on the variant 10 – in the first investigated year with the variant 3, in the second investigated year with the variant 4 and in the last year with the variant 5. In the course of three years, dry matter yield achieved the level of variants 3 and 4 despite the fact that on these variants the total nitrogen rate was higher.

The special role in the trial had the variant 9 with PK-fertilization absence in the second year as an alternative of annual phosphorus and potassium fertilization (variant 2). However, by fertilization absence yields decreased to the level of unfertilized control and the nutrient deficit was also manifested in lower dry matter yield in 1999.

In the total evaluation, it is necessary to refer to the low production potential of a grassland, the evidence of which are maximum yields achieved in the rate 240 kg/ha N (ca 5 t/ha). The limitation factor of higher nutrient rate application was the low portion of more productive grass species, which did not increase their occurrence even with higher nutrient rates. Lichner et al. (1977) also refer to the fact that species with low nutrient requirements, low species can sustain on poorer stands because they are not limited by species with high nutrient affinity.

From the economical viewpoint, a very important factor of fertilization adequacy is its efficiency that is production increment per 1 kg of supplied nutrients. Production efficiency of nutrients in particular years and within the whole investigated period is stated in Table 5.

The results of the first series (variant 1–5) demonstrate a very slight PK-fertilization efficiency. By supplying 60 kg N(+PK)/ha, the efficiency was increased to 15.27 kg/kg on the average. The efficiency then decreased by another N-rate increase, what indicates that annual application of these rates is purposeless on a particular stand. The similar results were also found out on the variant 10.

Lower values of production nutrient efficiency were achieved on the variants with the alternating N-application. The most expressive difference was found out between the variants 3 and 6. However, the variant 8 is interesting because in the last investigated year the efficiency of supplied nutrients raised to 18.62 kg/kg. On the other variants with N-nutrition absence, the higher efficiency than on the variant with an annual PK-application was found out (variant 2). It can be concluded that in the years with N-nutrition absence, the residual soil nitrogen is exploited, what causes the fertilization efficiency increase.

The specific phenomenon seems to be PK-fertilization absence on the variant 9 where production efficiency was decreased to 5.11 kg/kg of supplied nutrients. By this the uselessness of one-year PK-fertilization absence is intensified as well as the elimination of a given combination in nutrition of investigated grassland from a practical viewpoint.

Jančovič (1999) found out the higher dry matter increment per 1 kg of supplied nutrients on the variants with a periodical alternating of PK-fertilization and N-application or equal dry matter increment than on the variants annually fertilized by nitrogen. However, he observed higher production efficiency with alternating N-application in comparison with a variant fertilized annually only by PK.

REFERENCES

Holúbek R. (1991): Produkčná schopnosť a kvalita poloprírodného trávneho porastu v mierne teplej a mierne suchej oblasti. Poľnohosp. Veda. Veda, Bratislava.

Jančovič J. (1999): Vybrané biologické, produkčné a kvalitatívne charakteristiky trávnych porastov zväzu *Cynosurion* ovplyvnené hnojením. Monografia. SPU, Nitra.

Jančovič J., Vozár Ľ. (1999): Changes in grass phytocenosis after temporary cessation and repeated fertilization of stands. Sci. Agr. Bohem., *30*: 149–158.

Klapp E. (1971): Wiesen und Wieden. Paul Parey Verlag, Berlin-Hamburg.

Klimeš F. (1990): Effectiveness of phosphorus in the nutrition of grassland. Rostl. Výr., *36*: 529–535.

Klimeš F., Slípka B., Kobes M., Voženílková B. (2004): Uplatnění metody náhodných sekvencí při matematicko-statistických analýzách experimentálních dat v lukařství a pastvinářství. In: Coll. Sci. Pap., Fac. Agr. České Budějovice, Ser. Crop Sci., *20:* submitted.

Krajčovič V., Belej J., Dančík J., Folkman I., Holúbek R., Kováč A., Labuda J., Lichner S., Pačuta M., Tomka O., Vološin J. (1968): Krmovinárstvo. Príroda, Bratislava.

Lichner S., Morháč P., Šanta M., Folkman I., Šinkovic J., Kvietok J., Lobotka I. (1977): Lúky a pasienky. Príroda, Bratislava.

Martens K., Beek E. van, Kuijken E. (1998): Restoring botanical diverzity by reintroduction plant species. In: Ecological aspects of grassland management, 17th EGF Meet.: 461–464.

Rychnovská M., Balátová-Tuláčková E., Bár I., Fiala K., Gloser J., Jakrlová J., Makušová Z., Tesařová M., Úlehlová B., Zelená V. (1987): Metody studia travinných ekosystémů. Academia, Praha.

Velich J. (1986): Studium vývoje produkční schopnosti trvalých lučních porostů a drnového procesu při dlouhodobém hnojení a jeho optimalizace. Videopres MON, Praha.

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ABSTRAKT

Vliv obnovy hnojení na produkční výkonnost trvalého travního porostu

Z experimentálního studia vlivu obnovy hnojení (po jeho tříleté absenci) na produkční schopnost trvalého travního porostu v oblasti Strážovských vrchů (střední Slovensko, nadmořská výška 640 m, asociace *Lolio-Cynosuretum* Tx. 1937, experimentální období 1997 až 1999) vyplývá, že uplatnění každoroční aplikace dávek 60 až 120 kg N(+PK)/ha vede k velmi rychlé obnově produkční výkonnosti při vysoké výnosové stabilitě i produkční účinnosti dodaných živin (přírůstek výnosu 15,3, resp. 13,6 kg sušiny/kg NPK, 23,1, resp. 19,1 kg sušiny/kg N). V rámci intervalu dávek 120 až 240 kg N(+PK)/ha klesají hodnoty průměrné mezní produkce 1 kg N (8,64 kg sušiny) ve srovnání s intervalem dávek 60 až 120 kg N(+PK)/ha téměř na polovinu a ve srovnání s intervalem 0 až 60 kg N(+PK)/ha dokonce téměř na jednu třetinu. Při uplatnění střídavé aplikace živin v jednotlivých letech (PK-NPK-PK, PK-0-PK, N_{60}PK-N_{120}PK-N_{240}PK) vzrůstá výnosová variabilita v čase (V_x = 25,56–43,64%) několikanásobně ve srovnání s pravidelnou aplikací stejných dávek živin (V_x = 5,26–10,42 %).

Klíčová slova: střídavé hnojení; dusík; produkce nadzemní fytomasy; obnova hnojení

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