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EFFECTS OF RATES AND NUTRIENT RATIOS ON PRODUCTION AND QUALITY OF PHYTOMASS AT FERTILISER APPLICATION TO AN ALLUVIAL MEADOW

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The research objective was to assess effects of fertiliser application rates and nutrient ratios on production and quality of grassland at an alluvial meadow. The initial sward type was *Festucetum pratense* association. A field trial was established in the western part of "Zvolenská kotlina" basin (altitude 350 m) and consisted of ten fertiliser treatments: zero-fertilised sward (control); fertiliser P and K application; rates of 50, 100, 150 and 200 kg N/ha at two ratios of N : P : K nutrients, namely the low N : P : K ratio (1 : 0.3 : 0.8) and the high one (1 : 0.15 : 0.4), respectively. The grassland was utilised by three cuts. Dry matter (DM) production and herbage quality were determined at each of the cuts. The yield of DM was higher with the rates of 50 and 100 kg N/ha applied at the high nutrient ratio than at the low ratio. Over the research period, the highest DM production was recorded at the treatment with the low nutrient ratio and the highest N rate applied. The content of crude protein (CP) was increasing with the rising fertiliser N rate and the increase in CP was higher at the low nutrient ratio treatments. The zero-fertilised control also provided sufficient CP content. The low nutrient ratio resulted in higher P and K content than the high one. The lowest content of P and K was recorded at the control. The highest P content was found at the treatment with the fertiliser P and K applied. The highest K content was recorded at the 2nd cut, but decreased at the 3rd cut in all the treatments. The content of Ca was rising towards the 3rd cut. The content of nutrients was higher at the treatments where the high ratio was used. The content of Mg in DM was higher at the treatments with the high nutrient ratio and the high N fertiliser rates. The content of Mg was increasing in the 2nd cut at all the treatments.

Key words: alluvial meadow, long-term fertilising, herbage quality, production, permanent grassland

The fertiliser application ranks among the factors intensifying improvement of permanent grassland and is decisive not only for good yield and quality of forage, but also for good condition and long life of sward (Rataj 1996). The level of fertilising has a notable impact on the botanical composition and consequently, on the quantitative and qualitative aspects of production. Compared to arable crops, grassland nutrition has some peculiarities, e.g. a considerable amount of organic residues in soil is a rich source of released available nutrients; different ability of roots to take nutrients from more or less accessible forms; high number of symbiotic plants; dense representation of micro- and macro-edaphone not only supports, but also intensifies the effects of fertiliser application. Overall success of fertilisation depends on the initial state of grassland, the availability of water, the soil and climatic conditions, the method and frequency of utilisation and on the length of time over which the fertiliser is applied systematically (Slamka *et al*. 2006). The systematic and relatively long-term intensive application of nitrogen (N) fertiliser increases herbage and dry matter (DM) yields only during a limited period of time which is followed by sward degradation, decreased yields and the fertilisation ceases to be effective and economic (Rataj 1996).

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The content of crude protein (CP) is much higher in DM of leaves than in that of stems and moreover, it is also higher in legumes than in grasses. The application of high N fertiliser rates (more than 120 kg/ha) eliminates these differences and the CP content in grass may exceed the amount of CP in legumes (Holúbek *et al.* 2001).

The presented research aimed at studying the quality and production of herbage from an alluvial meadow at different fertiliser rates and nutrient ratios used the during fertiliser application.

MATERIAL AND METHODS

The research site “Veľká Lúka” (altitude 350 m; northern latitude 48° 37´; eastern longitude 19° 10´) was located in the protection zone of “Sliač” spa, in the western part of “Zvolenská kotlina” basin. The edaphic conditions at the research site were as follows: geological substratum – the alluvial soil was loamy fluvisol; initial soil pH in KCl = 6.03; available nutrients: P = 6.16 mg/kg and K = 96.6 mg/kg. The initial sward type was *Festucetum pratense* association with 35 species (*Alopecurus pratensis* dominant) at the trial start (Table 2). Long-term mean rainfall over growing season is 428 mm; long-term mean annual rainfall 757 mm; mean daily temperature 8.2°C per year and 14.7°C over growing season (Figure 1).

The field trial has been established as randomised blocks with four replicates (plot size 32 m^2; 8 × 4 m) in 1961. This paper presents the research period of 2006–2009. The trial comprised the following 10 treatments (Table 1) with a range of fertiliser application rates: *Treatment 1*: zero-fertilised sward (control); *Treatment 2*: fertiliser P and K application; *Treatments 3, 4, 5 and 6*: fertiliser N, P and K application at the N : P : K ratio of 1 : 0.30 : 0.8, respectively; *Treatments 7, 8, 9 and 10*: fertiliser N, P and K application at the N : P : K ratio of 1 : 0.15 : 0.4, respectively. The trial treatments and the fertiliser application rates in detail are given in Table 1. The fertiliser nitrogen was applied as ammonium nitrate (LAD 27%), P was applied as “hyperkorn” (8.5%) and K as potassium salt (52.23%). The total rate of N fertiliser was split into two dressings which were applied in the early spring (65%) and after the 1st cut (35%).

Grassland was utilised by three cuts a year: the 1st cut – at the ear emergence of dominant grass species; the 2nd cut – approximately 6 to 8 weeks later; the 3rd cut – approximately 8 to 10 weeks after the 2nd cut.

The dry matter (DM) production was determined as follows: fresh herbage was weighed at the research site, DM content was determined in herbage (at 105°C) and the yield of DM was calculated per hectare. The herbage samples were oven-dried at 65°C and submitted to the chemical analysis to determine the content of nutrients (crude protein – Kjeldahl method (N × 6.25), content of P, K, Mg were determined in accordance with the Slovak technical standard STN 46 7093. The obtained data were subjected to analysis of variance (ANOVA) followed by *post hoc* comparison using the Tukey´s HSD test (Statit Custom QC for Windows).

T a b l e 1

Trial treatments

Treatments	1	2	3	4	5	6	7	8	9	10
Nutrient rates [kg/ha]	0	PK	1 : 0.30 : 0.8				1 : 0.15 : 0.4			
N	0	0	50	100	150	200	50	100	150	200
P	0	22	15	30	45	60	7.5	15	22.5	30
K	0	41.5	40	80	120	160	20	40	60	80

RESULTS AND DISCUSSION

Over the growing seasons of the research period, mean air temperature was rising from 15.98°C in 2006 to 17.06°C in 2009, except for the year 2008 when the mean temperature was 0.02°C lower than in 2006, especially in the cool months of April and September, as given in Figure 1. Total monthly rainfall over the growing seasons decreased in 2006 and 2007, then increased to 389 mm in 2008 and decreased by 74 mm in 2009. The rainfall was extremely low in April in 2007 (0 mm) and 2009 (9 mm), respectively. Only in June 2009 the rainfall over growing season increased.

Table 3 and Figure 2 present the yields of dry matter and increments of DM yields throughout the research period of 2006–2009. In 2008, the lowest DM yield was recorded at all the treatments, due to the rainfall deficiency in the early (April, May) and in the late months (August, September) of growing season. The Treatment 1 (control) was characterised by low DM production (2.63–4.91 t/ha).

By comparison with the control, the fertiliser P and K application increased yields in all the cuts and years, except in 2009 (Table 3). The highest increase was recorded at the 2nd cut in 2006 (more by 1.07 t/ha than Treatment 1 – the control). In 2007 and 2009, the DM yields decreased at the 2nd and 3rd cuts. Holúbek *et al.* (2007), Honsová *et al.* (2007) and Jančovič *et al.* (2009) reported that the fertiliser P and K application itself increased the yield variability, mainly as a result of higher variability in the proportion of grasses and legumes in sward at the cuts.

The application of nitrogen significantly increased the DM production nearly in all the cuts and years ($P < 0.01$) and influenced also the total yield over the research period (Table 6). The variability in the yield increase under the rising N rates was found in agreement with Velich (1986), Holúbek (1991), Glaba and Kacorzykb (2011) and other authors studying the grassland nutrition.

An exception was found at the 2nd cut in 2007 when the highest DM production was recorded at the zero-fertilised control. Over the given period, the significantly highest DM production ($P < 0.01$) was recorded at Treatment 6 with the highest N rate and the low nutrient ratio applied (Table 6). The highest total DM yield for the whole research period was also found at Treatment 6 in all the years, except for the year 2006, when the lowest DM yield (5.7 t/ha) was recorded there. In the years 2006, 2008 and 2009, respectively, the application rate of 50 kg N/ha with the low nutrient ratio resulted in higher DM production at Treatment 3 than at the comparable Treatment 7 with the high ratio of nutrients. With the high N rate (100 kg/ha) and the high nutrient ratio (Treatment 8), the DM yield was higher than that at Treatment 4 with the low nutrient ratio. This was not the case in 2008 when the production of DM was 4.61 t/ha at Treatment 8,

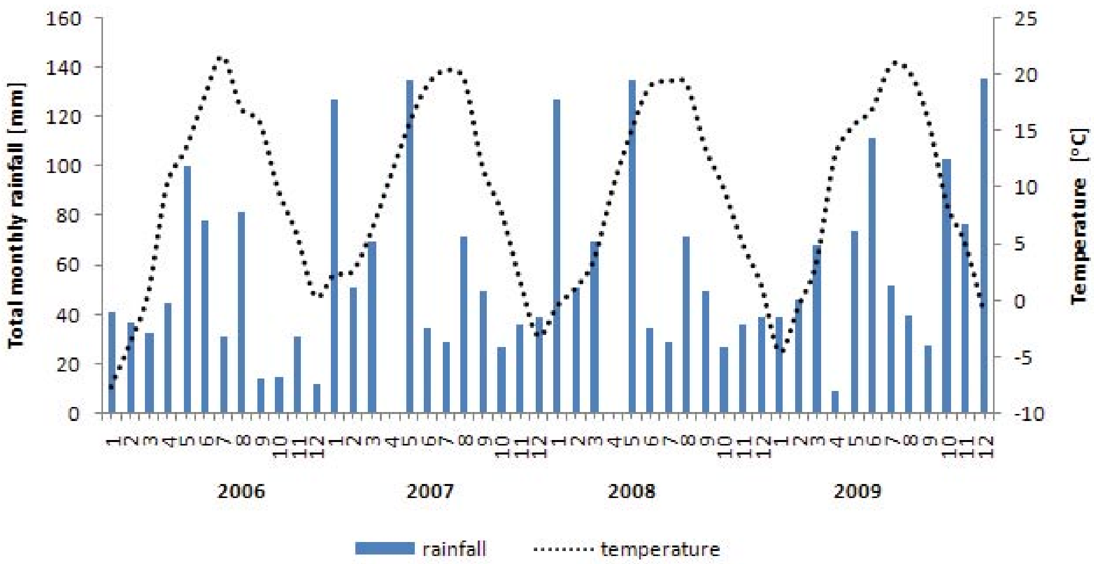


Figure 1. Mean monthly temperature [°C] and total monthly rainfall [mm] at "Veľká Lúka" site

T a b l e 2

Botanical composition [%] at the 1st cut in 2006

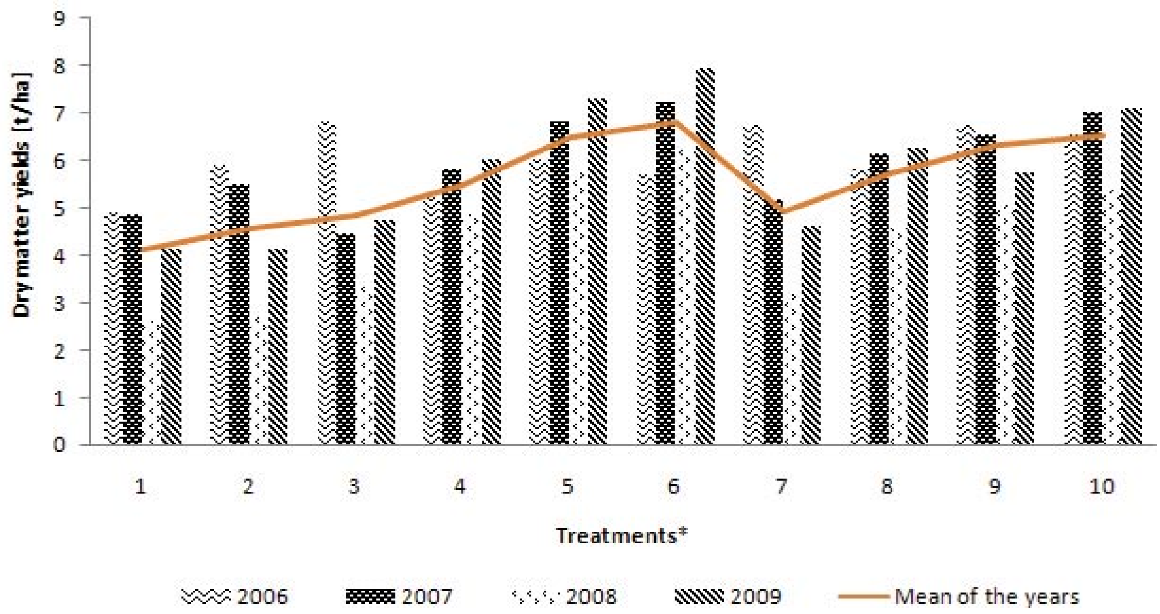
Botanical composition	Treatments*									
	1	2	3	4	5	6	7	8	9	10
Grasses	50	53	62	68	71	72	49	62	70	54
Legumes	13	8	7	3	5	4	3	4	2	2
Herbs	37	36	31	29	24	24	48	34	28	44
Bare ground	0	3	0	0	0	0	0	0	0	0
Alopecurus pratensis L.	3	5	3	5	6	5	2	5	5	2
Anthoxanthum odoratum L.	20	20	30	10	10	12	20	26	25	15
Arrhenatherum elatius L.	–	8	1	9	15	20	7	7	10	15
Avenastrum pubescens Dumort.	1	–	1	1	2	1	2	2	3	2
Bromus erectus Huds.	–	–	–	–	1	–	1	–	–	–
Carex spp.	6	–	6	–	–	–	1	–	–	–
Dactylis glomerata L.	3	2	4	–	2	–	–	3	4	2
Deschampsia caespitosa (L). P. Beauv.	–	–	–	–	–	–	–	–	–	–
Elytrigia repens L.	+	–	–	–	–	–	–	–	–	–
Festuca pratensis Huds.	3	–	–	2	2	–	–	2	–	–
Festuca rubra L.	2	5	–	3	1	4	–	3	2	4
Lolium perenne L.	2	–	2	1	–	–	–	–	–	–
Phleum pratense L.	–	–	–	–	–	–	–	–	–	–
Poa annua L.	–	–	–	–	–	–	–	–	–	–
Poa pratensis L.	10	10	15	15	22	18	10	8	12	10
Trisetum flavescens (L.) P. Beauv.	–	3	2	22	10	12	6	5	8	4
Lotus corniculatus L.	3	–	1	–	–	–	–	–	–	–
Medicago lupulina L.	–	–	–	–	–	–	–	–	–	–
Trifolium repens L.	7	5	2	1	1	–	1	3	1	1
Trifolium pratense L.	3	3	4	2	4	3	2	1	1	1
Vicia tenuifolia L.	–	–	–	–	1	–	–	–	–	–
Acetosa pratensis Mill.	–	1	2	2	2	–	3	2	3	–
Achillea millefolium L.	5	6	3	4	2	4	7	4	3	3
Campanula patula L.	+	–	+	–	–	1	+	+	1	+
Capsella bursa pastoris (L.) Medik.	–	–	–	+	–	–	–	–	–	–
Cirsium arvense L.	–	1	–	–	–	–	–	–	+	3
Cirsium canum (L.) Scopp.	–	–	–	–	–	–	–	–	–	–
Daucus carota L.	1	4	–	+	+	1	2	1	2	2
Galium mollugo L.	–	1	–	–	–	–	+	1	2	3
Geranium pratense L.	–	–	–	–	–	–	+	–	+	–
Geranium robertianum L.	–	–	–	–	–	–	–	–	–	–
Glechoma hederacea L.	–	–	–	–	+	+	+	1	–	1
Jacea pratensis Lam.	2	1	1	2	1	–	–	+	–	2
Leontodon hispidus L.	10	3	8	5	6	5	10	10	–	4
Leucanthemum vulgare Lam.	3	3	1	2	1	2	2	1	2	5
Plantago lanceolata L.	–	6	5	4	6	4	12	2	2	5
Plantago major L.	6	–	3	2	1	1	2	1	–	–
Prunella vulgaris L.	–	–	–	–	–	–	–	–	–	–
Ranunculus acris L.	2	3	3	2	2	2	3	4	5	4
Salvia pratensis L.	–	–	+	–	–	–	–	–	–	–
Stellaria graminea L.	–	3	1	–	+	1	4	2	2	2
Taraxacum officinale auct. non Weber.	5	4	2	4	2	2	2	3	4	7
Tragopogon orientalis L.	–	–	–	–	–	–	–	+	+	1
Veronica verna L.	2	–	2	2	1	1	1	2	2	1

+less than 1%, *see Table 1

but it was 4.86 t/ha at Treatment 4. Similar results (approx. 5 t/DM/ha), but with the maximum fertiliser rate (240 kg N/ha) were reported by Vozár (2009) from the trial at "Chvojnica" site. There had been reports of DM production decreasing from the 1st to the 3rd cut (Velich 1986). Our research data showed slight variations. In both 2007 and 2009, the DM yield was higher in the 2nd cut than at the 1st one, namely at the non-fertilised control as well as at Treatment 3 (50 kg N/ha and the low nutrient ratio). Based on his trials, Fiala (2002) pointed out that neither the long-term fertiliser application of as much as 300 kg N/ha nor the grassland utilisation by three cuts disturbed the ecological stability. The DM production rises while the nitrogen fertiliser rate is extended up to 150 kg N/ha and both the forage quality and production efficiency are increased. The most stabile treatments appear to be those where the low and medium rates of nitrogen fertiliser (50 and 150 kg N/ha + PK) are applied. This conclusion was drawn also in our research. Honsová *et al.* (2006) had carried out trials on a valley meadow at "Černíkovice" site and consequently, they confirmed the hypothesis of DM yields depending on the amount of nitrogen applied. At the control, mean production of herbage was 2.6 t ha^{-1} and the highest production (8.95 t/ha) was recorded at the treatment with the $N_{200}P_{40}$ K_{100} application rate.

Figure 2 gives the DM increase in comparison to the zero-fertilised control. The highest increase in DM yield (by 138.02%, i.e. 3.63 t/ha) was recorded at Treatment 6 in 2008 (200 kg N; low nutrient ratio). Over the research years, high increase in DM yield was recorded at Treatment 3, except for the year 2007 when a decrease by 8.2% was found. Averaged over the research years and in comparison with the control, the increase in DM was higher at the treatments with identical rates of nitrogen and high ratio of nutrients (19.56 % at Treatment 7 and 37.92% at Treatment 8) than those with the low nutrient ratio. It was the opposite situation at Treatments 5 and 6 with the high rates of nitrogen fertiliser and the low nutrient ratio (increase by 56.76% and 64%) in comparison with the treatments with the high nutrient ratio (increase by 45.65% and 57.49%).

Hejcman *et al.* (2010) and Holúbek *et al.* (2007) reported that the content of nutrients in herbage DM decreased with the reduction of available nutrients in soil and decreased also with increasing yield due to the so called dilution effect in the grown-up biomass. The quality of dry matter is defined by the mineral and organic composition (Whitehead 2000; Lichner *et al.* 1983).



*see Table 1

Figure 2. Dry matter yields during 2006–2009

T a b l e 3

Dry matter yields [t/ha]

Treatments*	0	PK	1 : 0.30 : 0.80				1 : 0.15 : 0.40			
	1	2	3	4	5	6	7	8	9	10
2006										
1st cut	3.07	2.62	3.88	2.23	2.59	2.22	3.80	2.60	3.40	2.84
2nd cut	0.92	1.99	1.86	1.81	2.27	2.17	1.50	1.99	2.27	2.60
3rd cut	0.92	1.31	1.10	1.18	1.17	1.31	1.46	1.23	1.07	1.12
∑	4.91	5.92	6.84	5.22	6.03	5.70	6.76	5.82	6.74	6.56
2007										
1st cut	0.94	2.16	1.79	2.64	3.11	3.25	1.72	2.34	3.08	3.21
2nd cut	2.92	2.41	1.93	2.36	2.61	2.85	2.41	2.63	2.25	2.89
3rd cut	1.01	0.94	0.75	0.85	1.12	1.15	1.06	1.19	1.21	0.95
∑	4.87	5.51	4.47	5.85	6.84	7.25	5.19	6.16	6.54	7.05
2008										
1st cut	1.30	1.19	1.83	2.31	2.64	3.37	1.61	2.80	2.75	2.89
2nd cut	0.60	1.03	0.96	1.70	2.15	1.76	1.13	1.01	1.34	1.73
3rd cut	0.73	0.48	0.61	0.85	0.99	1.13	0.49	0.80	0.99	0.76
∑	2.63	2.70	3.40	4.86	5.78	6.26	3.23	4.61	5.08	5.38
2009										
1st cut	1.15	1.81	1.79	2.23	2.01	2.43	1.50	2.03	1.87	2.29
2nd cut	2.15	1.71	2.11	2.74	4.49	4.38	2.03	2.97	2.87	3.54
3rd cut	0.86	0.62	0.84	1.07	0.82	1.16	1.10	1.26	1.03	1.27
∑	4.16	4.14	4.74	6.04	7.32	7.97	4.63	6.26	5.77	7.10
∑ yield over 4 years	16.57	18.27	19.45	21.97	25.97	27.18	19.81	22.85	24.13	26.09
Mean of the years	4.14^{a}	4.59^{ab}	4.86^{bc}	5.49^{cd}	6.49^{e}	6.79^{e}	4.95^{bc}	5.71^{d}	6.03^{de}	6.52^{e}
SEM	0.533	0.730	0.720	0.274	0.357	0.510	0.730	0.379	0.380	0.400

The values in the same row with different superscript letters are significantly different at $P < 0.01$ level for each variable Tukey´s HSD test
SEM – standard error of the mean

*see Table 1

Table 4 shows that the increasing nitrogen rate resulted in rising crude protein content. The highest CP content (201.68 g/kg) was found in the 1st cut at Treatment 5 with the rate of 150 kg N/ha and the low nutrient ratio, but the differences were not significantly different (Table 7). However, the decrease in CP content was very significant ($P < 0.01$) by comparison between the years.

The highest CP content was recorded mostly at the 1st cut, except for Treatments 1 and 3 to 10 in 2008 and 2009, respectively, when the CP content was higher at the 2nd cut, as shown by the statistically significant effect (Table 7). At the control, the highest CP content was recorded at the 2nd cut, except in 2009 (the 3rd cut). It may be concluded that CP content was higher at the treatments with the low nutrient ratio than at those with the high one. The results showed that the treatment without fertiliser application could provide the required quality of DM, as reported also by Michalec *et al.* (2007).

Some authors (Lichner *et al.* 1983; Krajčovič 1997; Holúbek 1991; Jančovič 1999) point out to the existing difference between the content of minerals in plants and that required by animals which can be mitigated by fertiliser application to grassland. Fiala (2002) reports that the long-term application of fertiliser has influ-

T a b l e 4

Crude protein content in dry matter of herbage [g/kg]

Years	Cuts	Treatments*									
		0	PK	1 : 0.30 : 0.80				1 : 0.15 : 0.40			
		1	2	3	4	5	6	7	8	9	10
2006	1st	112.67	152.00	134.90	171.34	201.68	163.03	135.29	157.59	179.27	168.82
	2nd	134.19	94.60	137.74	137.37	148.48	124.19	134.43	123.41	123.02	130.32
	3rd	129.56	122.99	122.31	131.18	120.49	127.84	153.81	120.84	112.25	116.93
2007	1st	135.23	144.24	134.66	153.51	152.41	138.71	154.19	152.41	137.87	156.57
	2nd	148.73	139.94	128.73	137.58	114.21	129.14	122.40	110.77	127.52	124.25
	3rd	120.87	116.83	116.96	127.21	137.26	136.69	117.39	125.03	118.91	124.75
2008	1st	112.92	130.47	124.15	129.04	123.80	115.83	122.95	118.00	116.26	119.87
	2nd	136.26	126.45	127.20	159.80	125.04	155.63	132.06	129.74	127.82	136.84
	3rd	113.86	116.61	124.36	116.32	121.58	108.59	114.49	125.51	119.71	112.50
2009	1st	93.75	105.43	105.89	108.05	94.94	123.82	113.31	115.57	118.90	119.00
	2nd	128.11	123.99	122.47	128.08	124.52	134.36	131.50	141.31	148.78	129.72
	3rd	130.21	121.23	131.80	133.92	130.41	139.12	138.09	131.67	132.75	134.29
Mean		124.70	124.57	125.93	136.12	132.90	133.10	130.83	129.32	130.25	131.15

*see Table 1

T a b l e 5

Mean content of minerals [g/kg]

Minerals	Cuts	Treatments*									
		0	PK	1 : 0.30 : 0.80				1 : 0.15 : 0.40			
		1	2	3	4	5	6	7	8	9	10
P	1st	1.95	3.31	2.49	3.00	3.30	3.04	2.08	2.07	2.47	2.45
	2nd	2.32	3.16	2.67	3.36	3.02	3.05	2.38	2.52	2.70	2.65
	3rd	2.41	3.42	2.80	2.96	3.27	3.19	2.59	2.43	2.82	2.48
K	1st	15.76	19.71	18.41	19.02	21.37	23.45	15.87	14.36	16.33	16.70
	2nd	15.43	17.04	15.52	16.64	16.88	18.78	20.18	20.47	19.71	23.25
	3rd	13.05	13.56	13.51	13.87	14.12	15.27	14.18	12.05	12.33	12.97
Ca	1st	8.29	10.80	9.49	8.25	8.04	7.49	8.41	7.86	8.37	7.85
	2nd	10.55	10.29	13.00	13.08	8.87	13.37	16.26	10.63	12.02	13.89
	3rd	15.07	16.94	13.30	13.75	12.53	11.75	11.19	12.74	14.69	12.28
Mg	1st	2.82	3.29	2.80	2.59	2.41	2.46	3.12	3.00	3.02	2.80
	2nd	4.65	3.71	4.81	4.35	3.22	4.27	4.78	3.66	4.51	4.54
	3rd	4.42	4.58	4.67	3.84	4.35	3.85	4.28	4.10	4.37	4.35

*see Table 1

T a b l e 6

The effect of years on dry matter yield [t/ha]

Year	Dry matter yield [t/ha]	SEM
2006	6.04^{bc}	0.212
2007	6.30^{c}	0.302
2008	4.39^{a}	0.414
2009	5.81^{b}	0.434

The values in the same row with different superscript letters are significantly different at $P < 0.01$ level for each variable Tukey´s HSD test
SEM – standard error of the mean

T a b l e 7

The effects of fertiliser application, cuts, and years on the nutrient content [g/kg]

Factor	Crude protein	P	K	Ca	Mg
Treatments*					
1	124.63^{a}	2.23^{a}	14.70^{a}	11.36^{ab}	4.10^{ab}
2	124.58^{a}	3.28^{d}	16.61^{b}	12.69^{b}	3.99^{ab}
3	126.00^{a}	2.65^{a}	15.70^{b}	11.87^{ab}	4.29^{b}
4	136.29^{a}	3.10^{bc}	15.39^{b}	11.67^{ab}	3.75^{ab}
5	133.08^{a}	3.20^{c}	17.34^{b}	9.81^{a}	3.52^{a}
6	133.05^{a}	3.10^{b}	19.12^{b}	10.79^{ab}	3.66^{ab}
7	130.81^{a}	2.35^{a}	16.72^{b}	11.82^{ab}	4.20^{ab}
8	129.06^{a}	2.33^{a}	15.64^{b}	10.38^{ab}	3.70^{ab}
9	129.86^{a}	2.66^{a}	16.10^{b}	11.64^{ab}	4.11^{ab}
10	131.18^{a}	2.54^{a}	17.56^{b}	11.14^{ab}	4.10^{ab}
SEM	2.385	0.065	0.790	0.541	0.169
Cuts					
1st	133.71^{b}	2.62^{a}	18.12^{b}	8.48^{a}	3.03^{a}
2nd	131.00^{b}	2.78^{ab}	18.26^{b}	12.09^{b}	4.31^{b}
3rd	124.93^{a}	2.83^{b}	13.49^{a}	13.42^{c}	4.28^{b}
SEM	1.283	0.045	0.397	0.246	0.089
Years					
2006	137.42^{b}	3.02^{c}	15.42^{a}	11.06^{a}	4.77^{b}
2007	132.83^{b}	2.73^{b}	19.74^{b}	12.82^{b}	4.61^{b}
2008	124.79^{a}	2.49^{a}	14.70^{a}	10.4^{a}	3.37^{a}
2009	123.88^{a}	2.73^{b}	16.49^{ab}	10.94^{a}	3.23^{a}
SEM	1.430	0.050	0.469	0.333	0.085

The values in the same row with different superscript letters are significantly different at $P < 0.01$ level for each variable Tukey´s HSD test; SEM – standard error of the mean

*see Table 1

ence on the content of mineral substances in total and at the individual cuts as well. The rising rates of nitrogen fertiliser are increasing the content of N, P and Na, but decreasing the content of Ca, Mg and K. The three-cut utilisation of sward is characteristic of increasing content of Ca and Mg and decreasing K content from the first to the last cut.

Mean content of minerals is given in Table 5. Averaged over the research period, the lowest P content (1.945 g/kg) was recorded at Treatment 1 (the control). Generally, the P content was low at all the cuts. The highest P content was found at Treatment 2 in all of the cuts (3.31, 3.16 and 3.42 g/kg, respectively) throughout the period of research. Nerušil *et al.* (2007) also reported that the long-term application of P and K fertilisers increases the legume dominance and consequently, also the content of P, Ca and Mg. An acceptable content was provided also by the Treatments 4, 5 and 6 with the low ratio of nutrients, respectively.

The lowest potassium content ranging between 13.05 and 15.76 g/kg was recorded at the zero-fertilised control. The K content was decreasing from the 1st to the 3rd cut at the treatments 1 to 6, respectively. The highest K content was found in the 2nd cut at Treatments 7 to 10, the ones with the high nutrient ratio. Similar conclusions are drawn by Ježíková and Lihán (1997) who report that the content of K and P in herbage is increasing at the high nutrient ratio. However, one cannot agree with their statement that the low N : P : K ratio results also in decreased content of P and K as well as in increased Ca content.

The highest calcium content was found at Treatment 3 in the 2nd cut. The content of Ca was increasing with the cuts, except for the Treatments 6, 7 and 10, respectively; the highest Ca content was found in the 2nd cut. Similar results were reported by Jančovič (1997).

The magnesium content was higher at the treatments with the high ratio of nutrients. The highest Mg content (4.81 g/kg) was found at Treatment 3 in the 2nd cut and moreover, at the same cut, the Mg content was 4.65 g/kg at the zero-fertilised control. Lichner *et al.* (1977) and Jančovič (1997) report that Mg content increases with the rising intensity of N fertiliser application. Table 7 shows the significant effects of the cuts on the mean content of P, K, Ca and Mg.

CONCLUSIONS

The results of research on the production and quality of herbage in relation to the long-term application rates of fertiliser and the nutrient ratios were concluded as follows:

Over the research period, the highest dry matter production was found at the treatment with the highest N (200 kg) rate and the low nutrient ratio applied 1 : 0.3 : 0.8 (total dry matter yield over the four research years was 27.18 t/ha).

The dry matter production was higher at the application of 50 and 100 kg N/ha fertiliser rates with the high nutrient ratio of 1 : 0.15 : 0.4.

The crude protein content was rising with the increasing N fertiliser rates. The highest crude protein content (201.68 g/kg) was found in the 1st cut at the treatment with the rate of 150 kg N/ha.

The low nutrient ratio of 1 : 0.3 : 0.8 resulted in high content of P, K and Ca, but in low Mg content in dry matter, respectively.

The content of K was rising in the 2nd cut and decreasing in the 3rd cut at all the treatments. The content of Ca was rising to the 3rd cut and the Mg content was increasing in the 2nd cut at all the research treatments.

Based on the research results, it was concluded that the ratio of 1 : 0.30 : 0.8 was more favourable, when considering the needs of animals.

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REFERENCES

FIALA, J. 2002. Vývoj ekologické a výnosové stability polopřírodního travního porostu při dlouhodobém hnojení a využívání [Development of ecological and yield stability of semi-natural grassland by its long-term fertilization and utilization]. In *Grassland Ecology VI: Proceedings of the International Scientific Conference*. Banská Bystrica : VÚTPHP, 10.–11.12.2002, ISBN 80-968890-7-9, pp.124–137.

GLĄBA, T. – KACORZYKB, P. 2011. Root distribution and herbage production under different management regimes of mountain grassland. In *Soil and Tillage Research*, vol. *113*, no. 2, 2011, pp. 99–104.

HEJCMAN, M. – SZAKOVÁ, J. – SCHELLBERG, J. – TLUSTOŠ, P. 2010. The Rengen Grassland Experiment: relationship between soil and biomass chemical properties, amount of elements applied, and their uptake. In *Plant and Soil*, vol. *333*, pp. 163–179. DOI: 10.1007/s11104-010-

0332-3.

HOLÚBEK, R. 1991. *Produkčná schopnosť a kvalita PTP v mierne teplej a mierne suchej oblasti* [The production capacity and quality of oversown grassland in a mild and slightly dry area]. Poľnohospodárska veda. Bratislava : Veda SAV, 1991, 132 pp.

HOLÚBEK, R. – JANČOVIČ, J. – BABEĽOVÁ, M. 2001. Kvalita sušiny sena z extenzívne hnojených trávnych porastov [The quality of dry matter in hay made from extensively fertilized grassland]. In *Agrochémia*, vol. *41*, 2001, no.1, pp.16–20.

HOLÚBEK, R. – JANČOVIČ, J. – GREGOROVÁ, H. – NOVÁK, J. – ĎURKOVÁ, E. –VOZÁR, Ľ. 2007. *Krmovinárstvo – manažment pestovania a využívania krmovín* [Forage production – management of crop-growing and utilisation] 1. vyd. Nitra: SPU, 2007. 420 pp. ISBN 978-80-8069-911-6.

HONSOVÁ, D. – SVOBODOVÁ, M. – MRKVIČKA, J. 2006. Dlouhodobé hnojení a jeho vliv na výšku trvalých travních porostů [Influence of long-term fertilization on actual sward height at permanent grassland]. In *Grassland – part of mountain agriculture and landscape: proceedings of international scientific conference*. SCPV Nitra : VÚTPHP Banská Bystrica, 27.–28.9.2006. ISBN 80-88872-56-1, pp. 241–245.

HONSOVÁ, D. – HEJCMAN, M. – KLAUDISOVÁ, M. – PAVLŮ, V. – HAKL, J. 2007. Species composition of an alluvial meadow after 40 years of applying nitrogen, phosphorus and potassium fertilizer. In *Preslia,* vol. *79*, 2007, no. 4, pp. 245–258.

JANČOVIČ, J. 1997. Mineral substances in natural grassland under different nitrogen fertilizing systems. In *Poľnohospodárstvo (Agriculture)*, vol. *43*, 1997, no. 3, pp. 207–216.

JANČOVIČ, J. 1999. Niektoré aspekty hnojenia trávnych porastov [Some aspects of fertilizer application to grassland]. In *Agrochémia*, vol. *39*, 1999, no. 1, pp. 12–15.

JANČOVIČ, J. – VOZÁR, Ľ. – BAČOVÁ, S. 2009. Effect of high nitrogen dose on floristical composition of grassland phytocenosis. In *Acta fytotechnica et zootechnica*, vol. *12*, 2009, no. 1, pp. 17–19.

JEŽÍKOVÁ, O. – LIHÁN, E. 1997. Dlhodobé hnojenie aluviálnej lúky pri dvoch pomeroch N: P : K [Long-term fertilizer application on an alluvial meadow at two ratios of N : P : K]. In *Poľnohospodárstvo (Agriculture)*, vol. *43*, 1997, no. 4–5, pp. 287–302.

KRAJČOVIČ, V. 1997. Štyri okruhy päťdesiatročných aktivít v odvetví krmovinárstva [Four spheres of fifty-year activities in the field of forage production]. In *Ekologické a biologické aspekty krmovinárstva*. Nitra : SPU, 1997. pp. 91–103.

LICHNER, S. – MORHÁČ, P. – ŠANTA, M. – FOLKMAN, I. 1977. *Lúky a pasienky* [Meadows and pastures] 1. vyd. Bratislava : Príroda, 1977, 423 pp.

LICHNER, S. – KLESNIL, A. – HALVA, A.1983. *Krmovinárstvo* [Forage production] 1.vyd. Bratislava : Príroda, 1983, 551 pp.

MICHALEC, M. – VARGOVÁ, V. – KOVÁČIKOVÁ, Z. 2007. Vplyv dlhodobého hnojenia a využívania TTP na kvalitatívne a kvantitatívne aspekty produkcie [Impact of long-term fertilizer application and utilization of permanent grassland on quantitative and qualitative production parameters]. In *Grassland Ecology VII : Proceedings of the International Scientific Conference.* Banská Bystrica : SCPV Nitra –VÚTPHP Banská Bystrica, 28.–30.11.2007. ISBN 80-8069-721-3, pp. 282–288.

NERUŠIL, P. – KOHOUTEK, A. – KOMÁREK, P. – ODSTRČILOVÁ, V. 2007: Koncentrace a odběr minerálních živin trvalým travním porostem na fluvizemi glejové [Concentration and uptake of mineral nutrients by permanent grassland on Fluvi-eutric Gleysol]. In *Multifunctional management and utilization of permanent grasslands in : proceedings from international scientific conference*. Rapotín : VÚCHS, 13.11.2007. ISBN 978-80-87144-00-8, pp. 164–168.

RATAJ, D. 1996. Trvalé trávne porasty [Permanent grassland] In KNOTEK, S. *et al.*: *Príručka krmovinára*. Banská Bystrica : VÚTPHP Banská Bystrica, 1996. 258 pp.

SLAMKA, P. – HANÁČKOVÁ, E. – HOLÚBEK, I. 2006. Vplyv hnojenia trávnych porastov na úrodu sušiny a dusíkatých látok [Dry matter and crude protein yields in fertilized grassland]. In *Scientia Agriculturae Bohemica*, vol. *37*, 2006, no. 2, pp. 49–57.

VELICH, J. 1986. Studium vývoje produkční schopnosti trvalých lučních porostů a drnového procesu při dlouhodobém hnojení a jeho optimalizace [Study of permanent grassland productivity at long-term fertiliser application and its optimisation] Praha : Videopress MON., 1986, 162 pp.

VOZÁR, Ľ. 2009. *Možnosti využitia prerušovanej výživy dusíkom v mätonohovo-hrebienkovom trávnom poraste* [Possibilities of using interrupted nitrogen nutrition in the *Lolio-Cynosuretum* type of grassland.] 1.vyd. Nitra : SPU, 2009. 84 pp. ISBN 978-80-552-0211-2.

WHITEHEAD, D.C. 2000. Nutrients elements in grassland: soil – plant – animal relationships. Wallingford, UK : CABI Publishing, 2000. 369 pp. ISBN 0-85199-437-7.

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