The effect of trophism level and exploitation intensity on the production characteristics of grassland community dominated by *Festuca arundinacea* Schreb.

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ABSTRACT

In 2004–2009, a small-plot trial was conducted on permanent grassland dominated by *Festuca arundinacea* Schreb. on the mesohygrophytic site in order to evaluate effects of four levels of nutrition: F_1 = without NPK fertilization, $F_2 = P_{30} + K_{60}$, $F_3 = N_{90} + P_{30} + K_{60}$, $F_4 = N_{180} + P_{30} + K_{60}$ kg/ha), four levels of cutting intensity (I_1-4, I_2-3, I_3-2, early, I_4-2, late cut) and their interactive influence, i.e. a total of 16 variants on the production of forage dry matter, production of crude protein (CD) and net energy of lactation (NEL) per hectare. The dominant influence of N-nutrition is documented by significant differences in forage dry matter (DM) production between the variants (with the exception of F_1/F_2) ranging from 4.41–4.80 to 8.44–9.83 t/ha. The effect of different exploitation level on the production is subdominant and no significant differences were found either in the production of forage DM (I_1-6.41 – I_2-6.59 – I_3-6.97 – I_4-7.50 t/ha) or in the production of nutrients. Management models to be recommendeed for the given type of sward with respect to the interactive influence, efficacy of forage production and quality are as follows: (a) three cuts/180 kg N + PK/ha with forage suitable for dairy cows; (b) two cuts/90 kg N + PK/ha with forage suitable for cattle breeds kept for meat.

Keywords: grassland; fertilization; cutting frequency; forage productivity; energy inputs and outputs

Results of project (Kameničky I) from the period 1974–1980 (Hrabě and Halva 1993) confirm indispensability of the effective N + PK subsidy as well as the above-mentioned significant differences in production between single variants of fertilization. The excessive dose (200 kg N/ha) leads to the considerable destruction of species diversity and to the impairment of harvested forage quality as pointed out by Velich (1986). With doses above 100 kg N/ha combined with a below- or above-average number of harvests, the process of succession would change either towards a fast ruderalization of swards or in the second case towards the invasion of rhizomatic, low-production and low-quality weed species (with a high share of *Elymus repens* etc.).

Partial results of the same experiment from other sites (Kohoutek et al. 2005, Nerušil et al. 2008) corroborate the significance of sward type and mention four cuts with a maximum dose of 180 kg N/ha as an optimum management model for the *Arrhenatheretum elatioris* association. Similar conclusions were published by Oerlemans (2006) under conditions of Germany. According to Skládanka and Hrabě (2008), the 3-cut exploitation system at a higher dose (180 kg N/ha) in the *Sanquisorba-Festucetum comutatae* association shows a clear advantage if compared with the traditional 2-cut exploitation and a lower fertilization level (90 kg N/ha).

Gruber et al. (2000) expanded on the given issue in relation to forage quality, stocking density (LU per hectar) of the area for cattle and resulting production level. As compared with the 3-cut exploitation, the high exploitation (4 cuts) was shown to result in a significantly lower DM production, i.e.

Supported by the Ministry of Education, Youth and Sports of the Czech Republic, Project No. MSM 6215648905 and by the Ministry of Agriculture of the Czech Republic, Project No. QH81280.

load (number of cattle units per hectare) and hence lower milk production. According to Schröder and Adolf (1997), intensive exploitation with a timely first cut often leads to the strengthening of the dominant species and hence to species composition changes and changes in the sward cover. As compared with the low cattle load (2 cattle units per ha), the high cattle load (4 cattle units per hectare) on the sward increases the NO_3-N wash-out loss three times if compared with the extensive load (17 kg N/ha). This is also corresponded to by the high concentration of nitrate N (N-NO_3) in seepage water (> 50 mg/L) of the intensively fertilized stands (Hüging et al. 1995). Kühbauch (1987) assume that the extensive 2-cut sward exploitation results in the impaired forage digestibility, i.e. in the increased export and load of nutrients from the excrements into the ecosystem. Velich (1986) points out the economical return of 1 kg N-fertilizer with the DM increase of ca 12 kg. According to Meinssen (1982), the energy return expended per 1 kg N-fertilizer (80.2 MJ) is covered by a DM increase of about 15 kg at a NEL concentration of 5.3 MJ/kg in DM.

The research of interaction between the level of trophism and multiple cuts in the grass community with the dominant representation of *Festuca arundinacea* presented by us can also be significant for the forage exploitation by grazing during a so-called extended autumn or winter periods. Wolf and Opitz von Boberfeld (2003) as well as Collins and Balasko (1981) inform that *Festuca arundinacea* is a favourable species as to the longer growing period, cold resistance and resistance to diseases.

MATERIAL AND METHODS

Production characteristics of grassland association dominated by *Festuca arundinacea* Schreb. (% dominance (D) 8.5–16.7% D) were studied in a small-plot experiment in 2004–2009 on the mesohygrophytic site operated by the Research Forage Station in Vatín and originally established in 1991. The locality is situated within the Protected Landscape Area of Žďárské vrchy Hills at 540 m a.s.l.; annual total precipitation amount 618 mm; mean annual temperature 6.9°C.

Differences in the production of DM (t/ha), CP (t/ha) and NEL (GJ/ha) were assessed in relation to four levels of trophism: F_1 (without NPK fertilization), F_2 (N_0 + P_{30} + K_{60} kg/ha), F_3 (N_{90} + P_{30} + K_{60} kg/ha), F_4 (N_{180} + P_{30} + K_{60} kg/ha). Another factor was the intensity of exploitation (number of cuts): I_1 (4 cuts), I_2 (3 cuts), I_3 (2 cuts – early), I_4 (2 cuts – late). The term of harvest was according to the respective variants 15 May, 30 May, 15 June and 30 June with an interval of subsequent harvests 45, 60, and 90 days. Each variant was replicated 4-times. Fresh weight of stands was established from an area of 10.0 m^2. Dry matter weight was calculated from the weight difference of fresh and dry forage samples (after drying at 60°C). Qualitative characteristics were established by NIRS (CP) and the NEL concentration was established by calculation. Results of the forage productivity and nutrients were processed by ANOVA and by the subsequent Tukey's HSD test in the STATISTIKA (version 8) programme. The production level trend was established by using linear regression Excel.

RESULTS AND DISCUSSION

Effect of nutrition level and fertilization on the production characteristics

Results concerning the effect of the N + PK level of fertilization show a dominant influence of this factor on the production of forage dry matter of the concerned association type on the mesohygrophytic site and with *Festuca arundinacea* as a dominant production species (Knot and Hrabě 2010). The results (Table 1) demonstrate the insignificance of differences in the production of forage dry matter between variants without the NPK fertilization (4.41 t/ha) and var. with PK-fertilization (4.80 t/ha). By the application of N-90 and N-180 t/ha a significant increase (2 to 2.2 fold) was achieved in dry matter production, i.e. 8.44–9.83 t/ha. Significant was also the difference between the two N-fertilized variants. CP and NEL values also increased up to 2.5 times by the application of N (Table 1). These results fully correspond with a number of previous scientific communications listed in introduction.

As compared with the production of CP in the stands with N + PK fertilization, the lower (relative) increase in the production of NEL (NEL/GJ/ha) was due to decreased NEL concentration and increased concentration of CP in forage DM.

Jančovič (1997) states in the association of *Lolio-cynosuretum* type without fertilization and with 120 kg the value of variation coefficient for DM production at v_x 37% and 17.6%, respectively, pointing out that permanent grass stands are capable of retaining adequate ecological stability

Table 1. Forage DM production in the permanent grassland (t/ha), production of crude protein (kg/ha) and production of NEL (GJ/ha) in relation to the level of trophism on average in 2004–2009, Vatín

Variation of fertilization		Forage DM production		Production of crude protein		Production of NEL	
		(t/ha)	rel. %	(kg/ha)	rel. %	(GJ/ha)	rel. %
F_1	–	4.41[a]	100.0	518.5[a]	100.0	23.28[a]	100.0
F_2	$P_{30}K_{60}$	4.80[a]	+8.8	551.6[a]	+6.4	24.75[a]	+6.3
F_3	$N_{90\,+}\,P_{30}K_{60}$	8.44[b]	+91.4	1019.0[b]	+96.5	43.39[b]	+86.4
F_4	$N_{180} + P_{30}K_{60}$	9.83[c]	+122.9	1382.2[c]	+166.6	50.34[c]	+116.2

Values followed by the same letter in each column are not significantly different (*P* < 0.05)

if sufficient supplementary energy is provided (e.g. N-fertilization). Holúbek and Kuzma (2003) demonstrated that the application of N-90 and N-180 kg/ha practically did not affect the values of production milk potential calculated in relation to NEL concentration in forage DM as compared with unfertilized stands or stands fertilized only with PK. The N-fertilization significantly increases the total production of CP and NEL from 1 ha. The authors consider the NEL production decisive for the valuation of stands efficacy.

According to Velich (1986), the production efficacy of 1 kg N, i.e. the gain of 44.7 kg DM (N-90) and 30.0 kg (N-180) calculated in economic terms is economically effective as compared with the unfertilized variant. However, between the variants of N-90 and N-180 kg/ha the detected DM gain of 15.4 kg is at the limit of economic profitability with respect to price of 1 kg N in fertilizer incl. VAT, which is 17.51 CZK. Similarly, from the viewpoint of energy balance, the concentration of 5.14–5.28 NEL/MJ in 1 kg forage DM (Knot and Hrabě 2010) would not guarantee according to Meinssen (1982) that the energy invested (80.2 MJ) into the production of 1 kg N in the mineral fertilizer pays back.

Effect of exploitation intensity on the production characteristics

As compared with the factor of nutrition, the results presented in Table 2 show a subdominant importance of this pratotechnical measure the efficiency of which is – as mentioned below – significant only in interaction with the corresponding level of nutrition, namely with N. Both extensive 2-cut variants have, as compared with the N + PK fertilized stands, insignificantly higher production of forage dry matter. Nevertheless, the late 1st cut reflects in low forage quality, esp. the concentration of N-substances, and consequently in their lower production from 1 ha (rel. by –27.7%). The number of harvests reflected insignificantly also in differences between the variants in total harvest NEL energy, which is obvious also from the range of yields, i.e. 36.87–34.90 GJ/ha. This corroborates indirectly the opinion of Abel (1983 in: Korner et al. 1997) about the overestimated level of NEL energy concentration in the forage of later harvested stands.

In general, the variant of 4 cuts is unfavourable in terms of production, operation and costs in spite of the higher forage quality according to Gruber

Table 2. Forage DM production in the permanent grassland (t/ha), production of crude protein (kg/ha) and production of NEL (GJ/ha) in relation to the number of harvests on average in 2004–2009, Vatín

Used method	Forage DM production		Production of crude protein		Production of NEL	
	(t/ha)	rel. %	(kg/ha)	rel. %	(GJ/ha)	rel. %
4-cut	6.41[a]	100.0	964.5[a]	100.0	35.13[a]	100.0
3-cut	6.59[a]	+2.8	917.7[a]	–4.9	34.93[a]	–0.6
2-cut early	6.97[a]	+8.7	793.8[a]	–27.7	34.90[a]	–0.6
2-cut late	7.50[a]	+17.0	795.2[a]	–27.5	36.87[a]	+5.0

Values followed by the same letter in each column are not significantly different (*P* < 0.05)

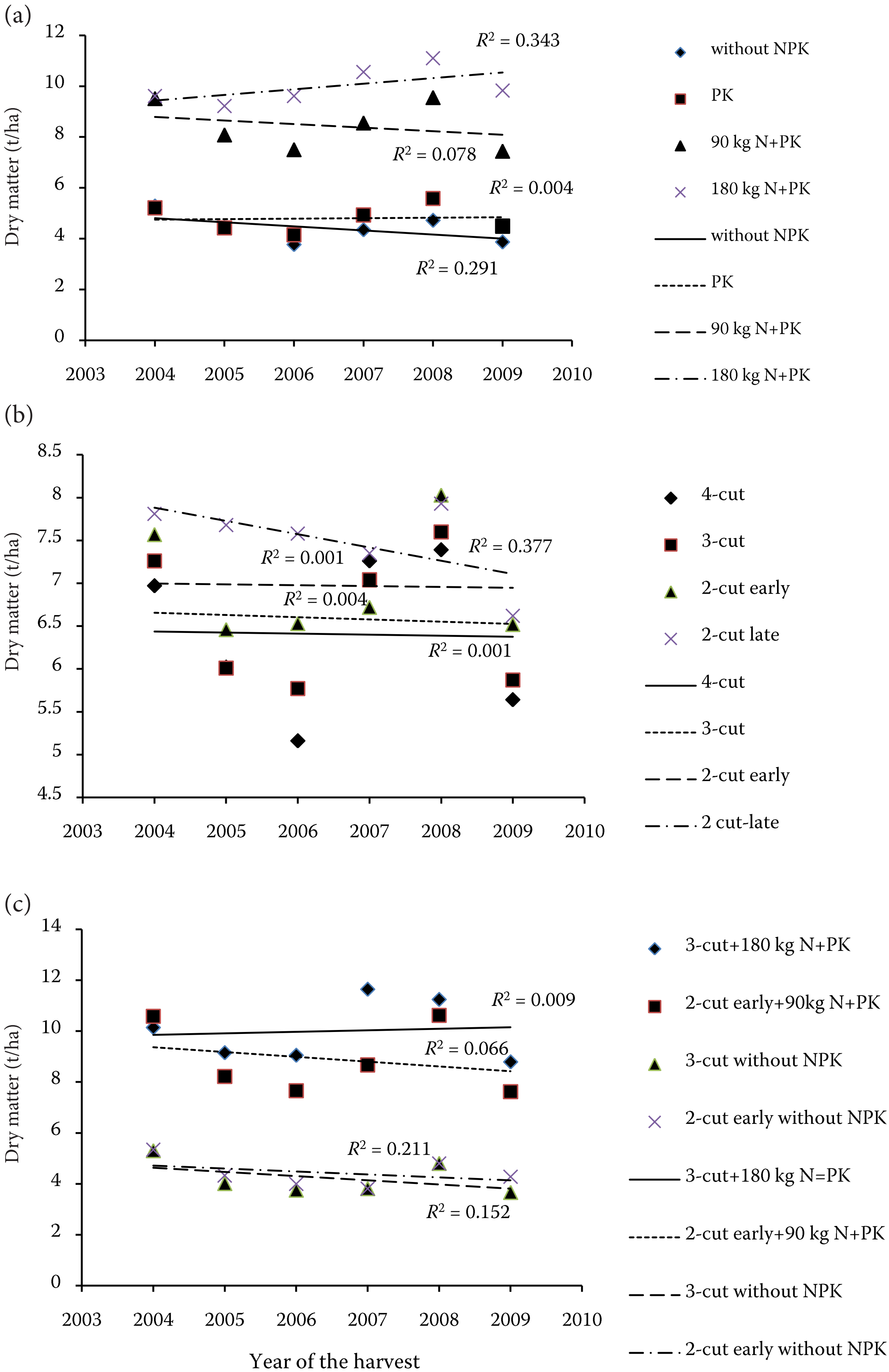

Figure 1. Correlation between the year of the harvest and the dry matter production (t/ha) in relation to (a) fertilization level (Regression analysis), (b) cutting frequency level (Regression analysis) and (c) nutrition level and cutting frequency level (Regression analysis), Vatín 2004–2009

Table 3. Qualitative characteristics of meadow herbage as related to the frequency of cuts and the level of N + PK fertilization-concentration of nutrients CP, CF (crude fibre) and NEL in dry matter. Vatín 2004–2009; weighted mean

Nutrients	3 cuts per year		2 cuts per year – early		Mean	SE
	without NPK	N 180 kg/ha	without NPK	N 180 kg/ha		
CP (g/kg)	117.4[a]	147.8[b]	111.1[a]	114.6[a]	119.44	21.73
CF (g/kg)	234.6[a]	241.7[a]	243.9[a]	267.5[a]	244.82	23.92
NEL (MJ/kg)	5.37[a]	5.29[a]	5.15[a]	5.06[a]	5.21	0.23

Values followed by the same letter in each column are not significantly different ($P < 0.05$)

et al. (2000). The authors claim that in addition to the lower cattle stocking density (cattle units load per hectare); costs of low forage production from this last and low-productive fourth cut are increased.

Development tendencies in the DM production of grassland

The graphical illustration (Figure 1a) of relation between the development of production in time and the level of trophism indicates that sustainable development or a mild increase occurs only in variants with the application of 180 kg N/ha + PK. The application of 90 kg N/ha and N-efficiency only at 60–70% (Velich 1986), the consumption of nitrogen removed with the harvest (in this case amounting to 88 kg N/ha/year) is not covered any longer. The significantly lower DM production in the variant without the NPK fertilization and in the variant with the PK fertilization serves as evidence that the N-supply from air pollutants (8–11 kg/ha – internal valuation), the level of nitrogen release from the soil environment as well as the low % D of the leguminous component (7.6–6.5% D), i.e. the low subsidy of biological nitrogen (20 kg/ha) are insufficient for a desirable fodder production and its sustainability in time. A similar evaluation of production trends in relation to stand exploitation (Figure 1b) indicated as acceptable also the variants with 3 cuts and 2 cuts (early 1st cut). The 2-cut variant with the late first cut exhibited a steady production decrease. The mildly decreasing production trend in variants with 3 and 4 cuts suggests a threshold for the establishment of the optimal stand exploitation, i.e. two strongly productive cuts and the third aftermath cut. With respect to the interactive influence of both pratotechnical measures in relation to economically and operationally most acceptable variants (Figure 1c), i.e. 3-cut exploitation and 180 kg N/ha and 2-cut exploitation and 90 kg N/ha it was demonstrated that the sustained – although insignificantly- increase of forage production is feasible only with using a more intensive level of pratotechnical measures at which the concentration of main nutrients would not be significantly reduced as shown in Table 3.

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Received on November 8, 2010

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