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EFFECT OF FERTILIZATION AND HARVEST FREQUENCY ON FLORISTIC COMPOSITION AND YIELDS OF MEADOW STAND

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Abstract

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The effect of fertilization and the harvest frequency on production and floristic characteristics of a meadow stand were assessed in a small plot trial established in 2003 in Vatín, Vysočina Region, the Czech Republic. Four levels of fertilization (none; $N_0 + P_{30} + K_{60}$ kg·ha^{-1}; $N_{90} + P_{30} + K_{60}$ kg·ha^{-1}; $N_{180} + P_{30} + K_{60}$ kg·ha^{-1}) were combined with four treatments of exploitation intensity (4 cuts per year, first cut on 15th May, every next after 45 days; 3 cuts per year, first cut on 30th May, every next after 60 days; 2 cuts per year, first cut on 15th June, next after 90 days; 2 cuts per year, first cut on 30th June, next after 90 days). Production of dry matter and proportions of guilds (grasses, legumes, and other species) were evaluated. Data from 2009–2011 were used in this paper. Yields of the dry matter increased along with increasing amounts of nutrients supplied and ranged from 3.8 t·ha^{-1} (non-fertilized) to 9.1 t·ha^{-1} (N_{180}PK). The nutrition level had a significant effect on spread of grasses, which reached maximal proportion of 52.3 % under N_{180}PK fertilization compared to 42.1% on non-fertilized plots. On the contrary, legumes flourished well in treatments without N-supply, attaining proportion of 6.8 % and 5.1 % on PK-fertilized and non-fertilized plot, respectively. With regard to the exploitation intensity grasses profited from extensive management by contrast to the group of other species which reached its maximum in swards harvested four times a year. Proportions of legumes did not show significant dependence on the cutting frequency.

permanent meadow, fertilization, harvest frequency, grassland management, floristic composition

In the Czech Republic, grasslands are mostly secondary communities developed in habitats originally occupied by forests, which represent a climax vegetation. Natural grasslands occur only in the areas with extreme conditions, where growth of woody vegetation is impossible. Thus most of the Czech grasslands developed as a result of human activities (Rychnovská *et al.*, 1985). In the course of time different types of management resulted into different types of grassland such as meadows and pastures. The maintenance of all these anthropogenic (or secondary, semi-natural) grasslands depends on management disabling progress of trees and shrubs (Klimek *et al.*, 2007). Primarily they were utilized to gain a fodder for a livestock. Except the production functions grasslands provide also ecosystem services and functions such as nutrient cycling, sequestration of carbon dioxide, prevention of soil loss and many others. Ability of grasslands to provide both production and ecosystem functions depends in addition to the others on the floristic composition (Chytrý, 2007). At the largest scale, the distribution of grasslands and their species diversity depends on climate. Particular grassland is affected by bedrock, soil, water regime, altitude, nutrient status, local climate, disturbance etc (Gibson, 2009). Then it follows that semi-natural permanent meadows, as a result of the concurrence of many factors, represent a great reservoir of biodiversity. Among anthropogenic activities, the fertilization appears to be the most important factor affecting floristic composition and yields, whilst the intensity of exploitation influences mainly quality of forage

(Mrkvička and Veselá, 2002; Hrabě and Knot, 2011). Especially nitrogen fertilization causes rapid shifts in the sward composition supporting growth of tufted grasses at the expense of legumes and other forbs (Silvertown *et al.*, 2006). Hrevušová *et al.* (2009) summarize, that the effect of nitrogen fertilization is apparent even 16 years after cessation of a long-term fertilization.

MATERIALS AND METHODS

A small plot trial was established in 2003 within the permanent meadow, which was set up in the 1990s. Site is located near Vatín, Vysočina Region, the Czech Republic, in the floodplain of the Oslava River, at 535 m above sea level. Annual rainfall averages 618 mm; mean annual temperature is 6.9 °C. For more detailed meteorological data see Tab. I. Soil is stagnosol on the quaternary fluvial deposits, bedrock is biotitic paragneiss. The trial was designed in the form of split blocks with four replications. Area of the plot was 10 m^2. There were four treatments of nutrition level combined with four treatments of exploitation intensity. Exploitation intensity is described in Tab. II. Nutrition level: no fertilization; $N_0 + P_{30} + K_{60}$ kg·ha^{-1}; $N_{90} + P_{30} + K_{60}$ kg·ha^{-1}; $N_{180} + P_{30} + K_{60}$ kg·ha^{-1}. Total amount of nitrogen was dosed in a ratio of 1:1:1:0, 1:1:1 and 1:1 in four-cut, three-cut and two-cut treatments, respectively. Proportions of guilds (grasses, legumes and other species) as well as each species were assessed by cover estimation method right before the first cut of the year. Yields of dry matter were calculated through using the weight difference of fresh and dry forage samples (after drying at 60 °C). Results from years 2009–2011 are presented in this paper. Results were processed by ANOVA and subsequent Tukey's HSD test in the STATISTICA software.

RESULTS AND DISCUSSION

Average production of dry matter was 6.3 t·ha^{-1}. It was significantly affected by level of fertilization (Tab. IV), while year and exploitation intensity had no significant effect (Tab. III and V). Yields of DM increased along with increasing amounts of nutrients supplied and ranged from 3.8 t·ha^{-1} in non-fertilized treatment to 9.1 t·ha^{-1} under doses of 180 kg of nitrogen per hectare. The results showed significant differences among all the levels of fertilization. With respect to the exploitation intensity, highest yields were attained under two-cut management (6.8 t·ha^{-1} in extensive and 6.3 t·ha^{-1} in low-intensive variant) compared to three- and four-cut variants (both 6.1 t·ha^{-1}). These results correspond to those obtained by Nerušil *et al.* (2008) in similar experiment from another site. They also refer to dominant effect of nutrition level and rather lower effect of exploitation intensity on the production of biomass. Hrabě and Knot (2011) also state that management with four cuts per year is unfavourable in terms of yields of dry matter, yet forage quality is higher due to younger

I: *Meteorological data of the experimental site*

	Temperature °C				Rainfall (mm)			
Year	2009	2010	2011	Average (1971–2000)	2009	2010	2011	Average (1971–2000)
January	–5.2	–5.8	–2.4	–3.3	24.5	81.3	42.0	45.4
February	–2.1	–3.8	–2.9	–1.7	73.4	16.8	9.5	30.6
March	2.0	0.8	2.7	2.1	96.4	36.5	27.3	41.6
April	11.0	6.6	9.0	6.6	4.6	64.8	37.5	38.0
May	11.9	10.8	12.0	12.2	85.0	117.3	53.0	66.5
June	13.8	15.3	15.9	14.9	125.3	79.9	78.6	75.0
July	17.0	18.7	15.5	16.4	148.7	131.6	129.6	79.5
August	17.2	16.1	17.1	16.3	70.2	159.2	73.3	62.5
September	13.5	10.2	13.3	12.0	19.9	73.9	95.2	53.2
October	6.1	5.0	6.5	7.2	66.8	11.0	41.4	38.4
November	3.8	4.2	1.3	1.8	43.2	43.3	0.6	40.6
December	–1.8	–6.1	0.2	–1.5	62.8	66.2	44.8	46.2

II: *Exploitation intensity*

Exploitation intensity	1st cut	2nd cut	3rd cut	4th cut
intensive	May 15	June 30	Aug. 15	Sept. 30
mid-intensive	May 30	July 30	Sept. 30	-
low-intensive	June 15	Sept. 15	-	-
extensive	June 30	Sept. 30	-	-

III: *Proportion of guilds and yields of dry mass in relation to year (average of all fertilization levels and exploitation intensities) (Using Tukey post-hoc test, values within the column marked with the same letter are not statistically different at the level of significance p = 0.95)*

Year	Dominance (%)				DM (t·ha^{-1})
	Total	Grasses	Legumes	Others	
2009	96.1^{a}	45.9^{a}	3.3^{a}	46.9^{a}	6.2^{a}
2010	96.6^{a}	46.2^{a}	3.4^{a}	47.1^{a}	5.8^{a}
2011	96.0^{a}	46.7^{a}	3.2^{a}	46.1^{a}	7.0^{a}
Mean	96.2	46.3	3.3	46.7	6.3

IV: *Proportion of guilds and yields of dry mass in relation to fertilization level (average of all years and exploitation intensities) (Using Tukey post-hoc test, values within the column marked with the same letter are not statistically different at the level of significance p = 0.95)*

Fertilization level	Dominance (%)				DM (t·ha^{-1})
	Total	Grasses	Legumes	Others	
0	96.1^{a}	42.1^{a}	5.1^{a}	49.0^{a}	3.8^{a}
$N_0 P_{30} K_{60}$	96.4^{a}	42.8^{a}	6.8^{b}	46.8^{a}	4.7^{b}
$N_{90} P_{30} K_{60}$	96.6^{a}	47.9^{b}	0.8^{c}	48.0^{a}	7.7^{c}
$N_{180} P_{30} K_{60}$	95.8^{a}	52.3^{c}	0.4^{c}	43.1^{b}	9.1^{d}
Mean	96.2	46.3	3.3	46.7	6.3

V: *Proportion of guilds and yields of dry mass in relation to exploitation intensity (average of all years and fertilization levels) (Using Tukey post-hoc test, values within the column marked with the same letter are not statistically different at the level of significance p = 0.95)*

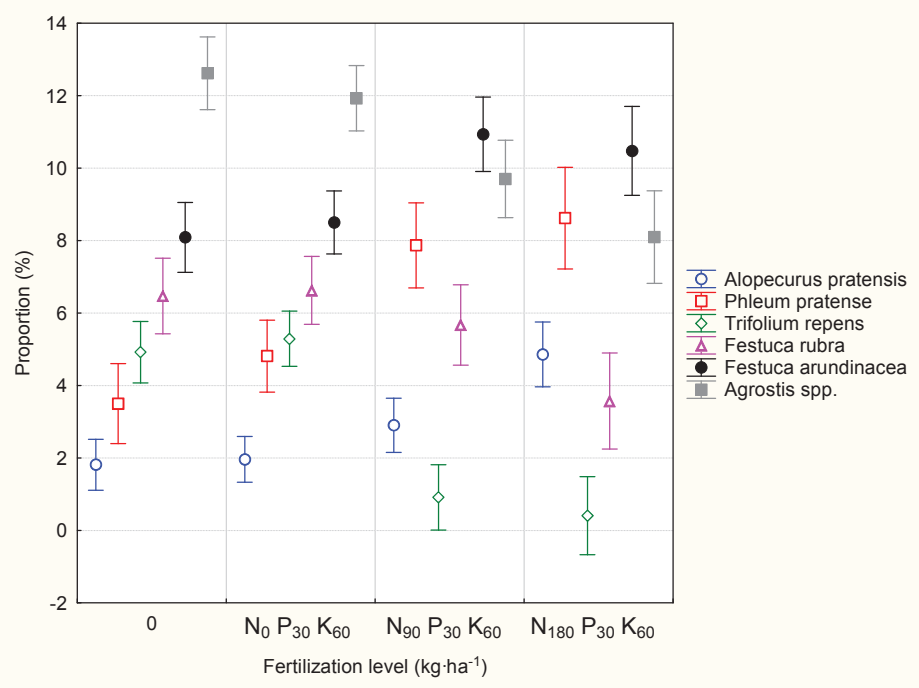
Exploitation intensity	Dominance (%)				DM (t·ha^{-1})
	Total	Grasses	Legumes	Others	
4 cuts	95.7^{a}	44.2^{a}	2.8^{a}	48.8^{a}	6.1^{a}
3 cuts	95.7^{a}	44.0^{a}	4.0^{a}	47.7^{ab}	6.1^{a}
2 cuts early	96.8^{a}	47.4^{b}	3.9^{a}	45.5^{bc}	6.3^{a}
2 cuts late	96.7^{a}	49.4^{b}	2.4^{a}	44.9^{c}	6.8^{a}
Mean	96.2	46.3	3.3	46.7	6.3

developmental stage of harvested forage. Especially concentration of N-substances is higher and thus total yield of crude protein is higher by more than 20% in comparison to two-cut variants.

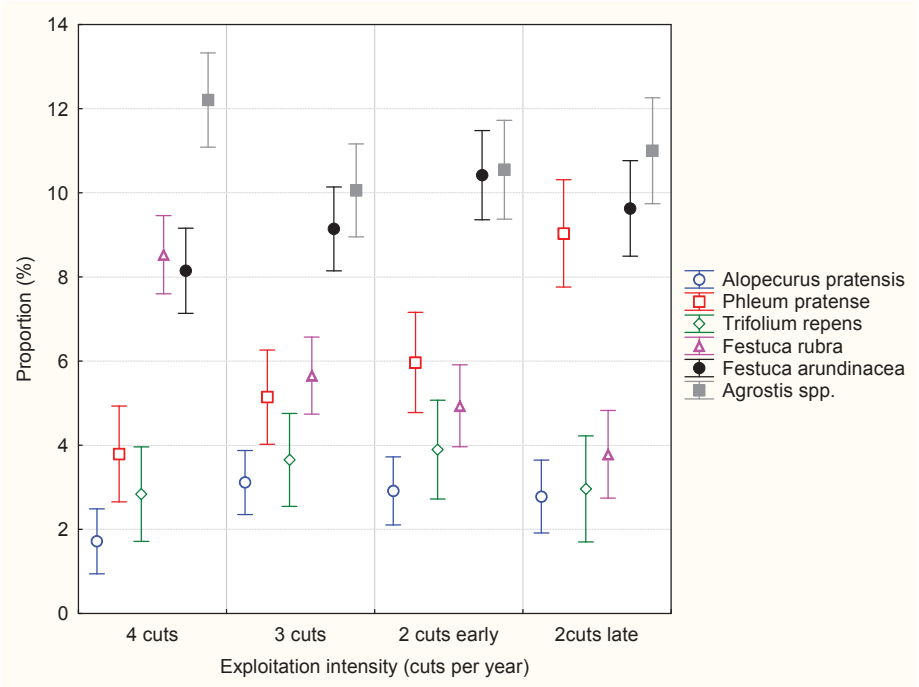
The average plant cover reached 96.2% and was not significantly affected by any of the evaluated factors. The fact that cover varied minimally may refer to a relative stability of the meadow community after more than 15 years of its existence. This corresponds to results obtained by Mrkvička and Veselá (2002), that total plant cover increases along with a progress of succession regardless fertilization rates.

Proportions of legumes ranged from 3.2% to 3.4% during evaluated years with no significant differences (Tab. III). There were also no significant differences between treatments of exploitation intensity (Tab. V). The proportion of legumes was significantly higher (6.8%) under PK fertilization compared to non-fertilized sward (5.1 %). Low proportions of legumes were detected in both N_{90} and N_{180} variants – 0.8% and 0.6%, respectively (Tab. IV). Most abundant leguminous species was White Clover (*Trifolium repens*). Presence of other members of family Fabaceae was rather incidental and did not show any dependence on applied types of management. The proportions of White Clover followed those of a whole group of legumes. Legumes were strongly suppressed by means of nitrogen fertilization on behalf of tall grasses e.g. Tall Fescue, Timothy or Meadow Foxtail (Fig. 1). There is a broad consensus among authors on the detrimental effect of nitrogen fertilization on leguminous plants. It is usually observed, that legumes are abundant in stands receiving phosphorus and potassium but not any nitrogen (Jančovič *et al.*, 2004; Silvertown *et al.*, 2006). Mrkvička and Veselá (2002) detected highest proportions of legumes in unfertilized plots, while PK-fertilized stands had by 50 percent lower rate of it's presence.

The group of other species was equal during evaluated years ranging from 46.1% to 47.1%. In respect to fertilization rates (Tab. IV) proportion of other species under N_{180}PK fertilization was the lowest (43.1%) and differed significantly from other three levels which varied from 46.8% (PK) to 49.0% (not fertilized). Concerning the exploitation intensity proportion of other species increased along with increasing intensification from 44.9% in extensive sward to 48.8% in sward harvested 4 times per year (Tab. V). This refers to higher light demands of herbs present in meadow stand (genera *Taraxacum, Plantago, Alchemilla* and other). However, the guild of other species encompasses great amount of plants



1: *Proportion of main grass and leguminous species in relation to fertilization level (average of all years and exploitation intensities)*



2: *Proportion of main grass and leguminous species in relation to exploitation intensity (average of all years and fertilization levels)*

with different demands and thus these results can be hardly generalized.

Also grasses showed just slight shifts in cover during years 2009–2011. Mean proportion was 46.3 % and it ranged from 45.9 % (2009) to 46.7 (2011). Regarding exploitation intensity proportions of grasses were significantly higher in two-cut variants: 49.4 % (late) and 47.4 % (early) compared to 44.0 % and 44.2 % under the 3-cuts and 4-cuts management, respectively. There is visible somewhat negative correlation to the group of other species. Some grass species appeared to be indifferent to exploitation intensity (e.g. Meadow Foxtail), while other species showed significant differences. In

general small or creeping grasses like Red Fescue or Bentgrass profited from high number of cuts per year and conversely tall grasses (Timothy, Tall Fescue) had benefit from two-cut management. As the production of dry matter was also higher on extensively managed plots, tall tufted grasses appear to be dominant production species as reported by Hrabě and Knot (2011). Responses of main grass species to exploitation intensity are presented in Fig. 2. Grasses showed also susceptibility to the fertilization level. They dominated (52.3%) on plots receiving $N_{180}PK$, which significantly differed from those receiving $N_{90}PK$ (47.9 %). Proportion of grasses in unfertilized and PK fertilized swards reached 42.1% and 42.8%, respectively. At the level of species (Fig. 1) there was visible positive effect of N-fertilization on Timothy, Meadow Foxtail and Tall fescue. On the contrary, Red Fescue and Bentgrass were not able to compete with tall grasses under nitrogen supply and their proportions declined. Mrkvička and Veselá (2002) detected both decrease (Orchard Grass) and increase (Tall Oat Grass) of proportions in loosely tufted grasses due to the long term N-fertilization.

CONCLUSIONS

Nutrients supply caused significant differences in production of dry matter between all levels of fertilization. Highest production was reached on plots receiving $N_{180}PK$ (9.1 $t \cdot ha^{-1}$ on average in all years and exploitation intensities). The effect of year and exploitation intensity on yield of the dry matter was not proved. Nitrogen fertilization affected positively proportion of grasses while other species and especially legumes were suppressed. With respect to exploitation intensity, grasses profited from less intensive management (2 cuts per year), while other species showed opposite trends. A proportion of legumes was equal across all treatments.

SUMMARY

The effects of fertilization rates and frequency and term of harvest on the production and floristic characteristics of a meadow stand were assessed in years 2009–2011. The small plot trial was established in 2003 in Vatín, Vysočina Region, the Czech Republic. Four treatments of nutrition level and four treatments of exploitation intensity were combined. Exploitation intensity: Intensive – four cuts per year, first cut on 15th May, every next after 45 days; mid-intensive – three cuts per year, first cut on 30th May, every next after 60 days; low-intensive – two cuts per year, first cut on 15th June, next after 90 days; extensive – two cuts per year, first cut on 30th June, next after 90 days. Nutrition levels: no fertilization; $N_0 + P_{30} + K_{60}$ $kg \cdot ha^{-1}$; $N_{90} + P_{30} + K_{60}$ $kg \cdot ha^{-1}$; $N_{180} + P_{30} + K_{60}$ $kg \cdot ha^{-1}$. Production of dry matter and proportions of guilds (grasses, legumes, and other species) and main grass and leguminous species were evaluated. Average production of dry matter was 6.3 $t \cdot ha^{-1}$ and it was significantly affected by level of the fertilization. Yields of DM raised along with increasing amounts of nutrients supplied and ranged from 3.8 $t \cdot ha^{-1}$ (non-fertilized) to 9.1 $t \cdot ha^{-1}$ ($N_{180}PK$). The nutrition level had significant effect on spread of grasses, which reached maximal proportion of 52.3% under $N_{180}PK$ fertilization compared to 42.1% on non-fertilized plots. On the contrary legumes flourished well in treatments without N-supply attaining proportions of 6.8% and 5.1% on PK-fertilized and non-fertilized plot, respectively. With regard to exploitation intensity grasses profited from extensive management (49.4% compared to 44.0% under 3-cut management) by contrast to the group of other species which reached its maximum in swards harvested four times per year. Proportions of legumes did not show significant dependence on the cutting frequency.

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