Influence of fertilization rates on species composition, quality and yields of the meadow fodder

J. Mrkvička, M. Veselá

Czech University of Agriculture in Prague, Czech Republic

ABSTRACT

Four variants in four replications were studied on permanent meadow stand on Czech and Moravian highlands. The altitude a.s.l. is 485 m, original growth type was *Dactylidetum*, association *Trifolio-Festucetum rubrae*. Four variants: control (without fertilization), 40 kg P + 100 kg K.ha^{-1}, 100 kg N.ha^{-1} (+ PK) and 200 N.ha^{-1} (+ PK) were evaluated. Botanical analyses of stands were done by the method of reduced projective dominance (D in %). The cut green matter was weighed up, mean samples for dry matter determination and chemical analyses were taken. Botanical composition of the meadow stand in 1991–2000 was not stabile and was changing due to nourishment. The yields of dry matter ranged within 10 years in the control variant from 1.07–3.42 t.ha^{-1} (in the plot fertilized by $P_{40}K_{100}$ 2.09–5.95 t.ha^{-1}, in the plots with nitrogen (+ PK) 2.29–6.52 t.ha^{-1}, resp. 3.74–7.61 t.ha^{-1}). According to the *t*-test, the yields of dry mass in experimental variants are significant at 95% level.

Keywords: permanent meadow stand; fertilization; species richness; yields; concentrations of elements

Botanical composition and the yields of meadow stands have been the result of an interaction of conservative and progressive ecological factors (Klimeš 1999). The portion of individual agro-botanical groups and their species on the yields formation and the fodder quality ranges according to the water and nutritious regimes, methods and intensity of utilization. Species variation of meadow stands causes a significant variation in the compound composition (Rychnovská et al. 1985). Water regime of the soil is one of the most significant factors, besides the nutrition regime, influencing the vitality, quality, occurrence and competitive ability and the yields of grass stands (Veselá and Mrkvička 1997). The dominant influence on the fodder quality is the growing phase, in which the plant occurs in the period of the harvest time. The ratio leaves/stems changes by the fodder senescence (Míka et al. 1997). The plant nutrition content in the fodder dry mass of the grass stands is a valuable indicator in the demands of rational cattle nourishment and is very important for its quality as a fodder for polygastric animals.

The fertilization of multiyear or perennial grass associations affects the fodder chemical composition indirectly, by differences in the species composition of the stand or directly by the change of the species nutrition. The species composition of the stand gradually relatively stabilizes and the portion of direct influence of fertilization on the fodder quality increases. This reality prevails after reaching the stage, when the permanent grass stand becomes the complex function of stand conditions again (Mrkvička and Veselá 2002). The most significant influence on the fodder quality is in nitrogen fertilization, mainly in the doses over 100 kg.ha^{-1}. The effect of used nitrogen can be manifested in a negative direction, depending on the botanical composition. Nitrogen concentration or nitrogen compounds (NC) in the fodder are increasing proportionally to the level of nitrogen doses, mainly with higher levels of fertilization.

Chemical composition of individual fodder species is affected by the phosphorus fertilization. The fodder quality is thus most favourably influenced. The K content in the fodder dry mass is in a narrow relationship to in the soil available K and to the level of potassium fertilization. The dicotyledonouos plants react most intensively upon the potassium doses. Filipek-Mazur and Mazur (1996) state, that the liming of grass stands increases the Ca, Mg, K, Mo concentration and decreases the fodder Mn, Zn, Co and Cu content. The Mg content in the dry mass in the grass stands is mainly determined by the weight portion of agro-botanical groups. Clover crops and some herbs such as (*Rhinanthus minor* L., *Plantago major* L., *Alchemilla vulgaris* L. etc.) are rich in magnesium. Klapp (1971) describes the Mg contents in the grass fodder dry matter 0.13%, in clover crops 0.24% and in herbs 0.32%.

The ash content in grass fodder is very variable (4–14%) in extreme conditions, but usually ranges between 7–10%. The fibre content in the fodder is a suitable orientation indicator of fodder nutrition value. It is in a narrow negative correlation with the digestibility of organic mass and digestibility of crude protein (DCP) content. From the point of view of cattle nourishment and a high utility, the fibre content in the fodder dry mass is very desirable until 23% (Labuda et al. 1982).

MATERIAL AND METHODS

The experiment was founded in 1976 on a plain permanent meadow of mesophytic character on the site of Senožaty (Pelhřimov district), which originated in the original grass stand sown in 1964. Original growth type was *Dactylidetum*, association *Trifolio-Festucetum rubrae*. The altitude a.s.l. 485 m, the average annual precipitation sum 641 mm, (402 mm during vegetation period), average annual temperature 7.0°C, Lang's rainfall factor 92. Depth of underground water level 0.6 m (0.3–1.0 m). Soil type pseudogley, soil species sandy loam, pH_{KCl} 5.1; % C_{ox} = 2.16; % N_{tot} = 0.39; C_{tot}:N_{tot} = 5.54. Maximum sorption capacity (*T*) = 25.0 mval per 100 g of soil; saturation of sorption complex by bases (*V*) = 52.0%. Four variants were evaluated: control (without fertilization), 40 kg P.ha^{-1} + 100 kg K.ha^{-1}, 100 kg N.ha^{-1} (+ PK) and 200 N.ha^{-1} (+ PK). The growth was exploited with three cuts, the first cut in phase in the early of throwing predominant species of grasses. Botanical analyses of stands were done by the method of reduced projective dominance (D in %). The cut green matter was weighed, mean samples for dry matter determination and chemical analyses were taken. According to the *t*-test, the yields of dry mass in experimental variants are significant at 95% level. The experimental methods have been previously presented (Mrkvička and Veselá 2002). The fodder samples were analysed in an accredited laboratory EKO-LAB Žamberk.

RESULTS AND DISCUSSION

The dominance of species and yields of meadow stands create a complex interaction. The priority here is in trophoseries, hygroseries and stand utilization. The portion of individual agro-botanical groups and their species in yield formation and the fodder quality ranges according to the level of fertilization, climatic conditions and edaphic factors.

It is evident (Table 1) that the botanical composition of meadow stands was in 1991–2000 not stabile and differed according to nourishment and ecological factors. The influence of unfavourable conditions can be partly im-

Table 1. Coverage of vascular plants (% D) in years 1991–2000

Species	Control		$P_{40}K_{100}$		$N_{100}P_{40}K_{100}$		$N_{200}P_{40}K_{100}$	
	1991	2000	1991	2000	1991	2000	1991	2000
Dactylis glomerata	1	1	10	10	2	5	10	5
Poa pratensis	5	15	25	25	25	20	24	28
Festuca rubra	5	15	7	7	15	10	14	15
Alopecurus pratensis	–	–	–	–	+	2	–	–
Trisetum flavescens	–	–	–	–	–	–	–	2
Anthoxanthum odoratum	3	1	3	3	2	3	1	3
Arrhenatherum elatius	+	+	5	4	15	20	25	20
Agropyron repens	–	–	–	–	–	2	–	–
Holcus lanatus	+	3	+	–	1	3	–	–
Agrostis stolonifera	5	2	–	–	–	–	–	–
Deschampsia caespitosa	–	–	+	3	–	–	–	2
Phleum pratense	–	–	–	–	–	–	–	+
SD grasses	19	37	50	52	60	65	74	75
Trifolium dubium	+	5	1	5	3	–	+	+
Trifolium pratense	3	+	1	5	+	+	–	–
Trifolium repens	3	10	8	5	7	2	–	–
Lathyrus pratensis	+	15	–	+	+	1	–	–
Lotus corniculatus	9	+	+	+	–	2	–	–
SD legumes	15	30	10	15	10	5	+	+
Taraxacum officinale	15	15	5	8	13	15	10	10
Alchemilla vulgaris	1	+	1	2	2	+	3	2
Achillea millefolium	+	1	2	8	–	4	2	1
Plantago lanceolata	4	2	2	+	–	+	–	+
Cerastium arvense	–	–	–	–	+	1	–	2
Leontodon autumnalis	10	–	5	–	–	–	–	–
Cardamine pratensis	–	–	–	2	–	–	–	–
SD other herbs	30	18	15	20	15	20	15	15
Total coverage of vascular plants	64	85	75	87	85	90	89	90
Number of species (D ≥ 1)	12	12	13	12	10	14	8	11
Number of species (D < 1)	13	17	13	16	12	10	11	9
Total number of species	25	29	26	28	22	24	19	20

(+) species with D < 1

Table 2. Changes of growth composition (in %) in relationship on fertilization of meadow stand

Changes of growth composition	Control	$P_{40}K_{100}$	$N_{100}P_{40}K_{100}$	$N_{200}P_{40}K_{100}$
Internal	18.00	11.00	15.00	12.00
External	22.00	6.00	7.50	0.50
Total	40.00	17.00	22.50	12.50

Table 3. Yields of dry matter ($t.ha^{-1}$) of meadow stand

Years	Control	$P_{40}K_{100}$	$N_{100}PK$	$N_{200}PK$
1991	3.40	4.37	6.52	7.61
1992	1.48	2.15	3.78	3.95
1993	1.07	2.09	2.29	4.09
1994	2.82	3.15	3.56	3.74
1995	3.26	4.37	4.67	6.53
1996	2.94	3.34	4.62	5.00
1997	3.42	3.56	4.73	5.24
1998	2.27	4.32	5.81	5.87
1999	3.35	5.95	6.50	7.43
2000	2.40	2.93	3.67	4.33
Average 1991–2000	2.64	3.62	4.61	5.38
Relatively in %	100.00	137.12	174.62	203.79

$\alpha_{0.05}$ = 1.47075

proved by the nitrogen fertilization. With the long lasting N-fertilization – mainly the freely clustering grasses – such as *Dactylis glomerata* L., decline, but according to our results *Arrhenatherum elatius* L. increased by 10 or 20%, resp. The increased nitrogen doses caused higher grass dominance and simultaneously decreased leguminous groups representation compared with PK-fertilization. Covering of significant dicotyledonous species (*Taraxacum officinale* L.) was almost stabile in all variants. The total dominance of agro-botanical species at the end of experimental period was always higher with exception of the variant fertilized by 200 kg $N.ha^{-1}$, where the stabile level was observed. The highest changes of growth composition were recorded with control variant. On the contrary, the lowest changes were detected with fertilization 200 kg $N.ha^{-1}$ (+ PK) (Table 2).

Table 4. The influence of fertilizing on yields of dry matter (1991–2000)

Variants of fertilizing	Number of cases	Average	Homogenous groups
Control	10	2.641	*
$P_{40}K_{100}$	10	3.623	**
$N_{100}P_{40}K_{100}$	10	4.615	**
$N_{200}P_{40}K_{100}$	10	5.379	*

t-test

The yields of dry matter ranged within the 10 years period with control variant from 1.07–3.42 $t.ha^{-1}$ in the area fertilized by $P_{40}K_{100}$ 2.09–5.95 $t.ha^{-1}$ and 2.29–6.52 $t.ha^{-1}$, 3.74–7.61 $t.ha^{-1}$ resp. in the areas with N-fertilization (+ PK). Significant differences in the yields in individual years were caused by different meteorological conditions. The phosphorus-potassium fertilization increased the yields by 37%, 100 kg $N.ha^{-1}$ (+ PK) by 75% and 200 kg $N.ha^{-1}$ (+ PK) by 104%, compared with the control (Table 3). Similar results have been presented in the growth-standing types Mrkvička and Veselá (1999) and others.

According to the *t*-test, the yields of dry mass in experimental variants are significant at 95% level (Table 4).

The nutrient content in dry mass of grass stands is a very valuable indicator for the level of the nourishment of grass stands and of the fodder quality. Concentration of macroelements and other mineral compounds in fodder dry mass depend on the weight portion in individual agro-botanical groups of grass stands. In the cutting fertility (50% of prevailing species coming to ears) the content of the main nutrients in fodder dry mass range according to the different data: 1.5–3.5% N, 0.15–0.40% P, 1.5 –5.5% K and 0.3–1.4% Ca. Firek and Szewczyk (1996) state that the nutrient content in the fodder of individual species in agro-botanical groups corresponds to the content of available nutrients in the soil and to the fertilization intensity. It is evident (Table 5) that the N concentration in the total yield ranged from 1.87 to 2.52%. At the same N fertilization and harvest time were mostly influenced by the portion of leguminous crops. The in-

Table 5. Mean contents (%) of ash, elements, crude fibre, and tetanic ratio K:(Ca + Mg) in the dry mass of meadow fodder stand in years 1991–2000

Variants	Ash	N	P	K	Ca	Mg	Crude fibre	K:(Ca + Mg)
1. Control	7.73	1.87	0.21	2.09	0.91	0.24	18.82	1.82
2. $P_{40}K_{100}$	6.95	2.10	0.28	2.00	0.72	0.22	18.93	2.13
3. $N_{100}P_{40}K_{100}$	5.96	2.33	0.25	1.68	0.51	0.21	22.60	2.33
4. $N_{200}P_{40}K_{100}$	5.70	2.52	0.21	1.72	0.58	0.22	23.91	2.15

crease in their weight portion in the fodder, cca by 10% represents the mean increase in the N content of fodder dry mass by 0.13% (Labuda et al. 1982).

The phosphorus content in the meadow fodder dry matter ranged between 0.21 and 0.28%. The phosphorus content in individual components of the grass stand is more similar and therefore its content changes more or less with the change in species composition. It depends more on the level of phosphorus fertilization. The potassium concentration in fodder dry mass depends on the weight portion of agro-botanical components of the meadow stands. In our experiment, it was slightly decreasing with the applied N doses. According to many domestic and foreign contributions the highest concentrations have been determined in dicotyledonous plants, which can affect the total content in fodder dry mass (Klesnil et al. 1978). The Ca content in dry mass of grass stands depends mainly on the species composition and changes caused by liming. Leguminous plants and other dicotyledonous species contain twice as much calcium compared with grasses. In the dry mass of grasses there is 0.54% Ca, in clover crops 1.79% and the other herbs 1.85% Ca. The magnesium content in fodder mass has been influenced by many factors, for example by the content of available Mg and pH in the soil and N- and K-fertilization. Further on, climatic conditions also influence the Mg content. A rainy weather can decrease the Mg content in the fodder dry matter (Labuda et al. 1982). The levels of Ca and Mg in our control areas and PK fertilized variants increased in comparison with the plots with N-fertilization. Firek and Szewczyk (1996) reached opposite results. They state higher contents of those macroelements in the fodder dry mass which depends on the N doses in the fertilizers. The potassium content in meadow fodder dry mass slightly overtakes the demands of cattle nourishments. Quotient K:(Ca + Mg), so called tetanic ratio, should not exceed the 2.2 level. In contrary, due to the influence of synergic relationship it increases by N-fertilization, mainly in the fodder in first cuttings. This ratio was slightly higher at the 100 kg $N.ha^{-1}$ fertilization level, within 10 years (Table 5). P and K concentration in the fodder is variable compared with the value corresponding to the demands of proper cattle nourishment. Fibre content is influenced by the harvest time, species maturity, botanical composition and fertilization. In our experiment the same percentage in the control area and PK-fertilization was determined. In the areas fertilized by nitrogen, the fibre content was higher (22.60 and 23.91%), probably due to the higher occurrence of *Arrhenatherum elatius* L.

The levels of elements in total harvests were influenced mainly by nourishment of growth and by the individual experimental years (Tables 6 and 7).

The floristic grass stand composition can be purposefully affected by fertilization which determines the yields and fodder quality.

Authors thank for financial support of this work provided project of MSM: 41210-0003.

Table 6. Samplings of macroelements ($kg.ha^{-1}$) according to the dry mass yields of control and $P_{40}K_{100}$ variants in years 1991–2000

Years	Control				$P_{40}K_{100}$			
	P	K	Ca	Mg	P	K	Ca	Mg
1991	7.14	71.06	30.94	8.16	12.24	87.40	31.46	9.61
1992	3.11	30.93	13.47	3.55	6.02	43.00	15.48	4.73
1993	2.25	22.36	9.74	2.57	5.85	41.80	15.05	4.60
1994	5.92	58.94	25.66	6.77	8.82	63.00	22.68	6.93
1995	6.85	68.13	29.67	7.82	12.24	87.40	31.46	9.61
1996	6.17	61.45	26.75	7.06	9.35	66.80	24.05	7.35
1997	7.18	71.48	31.12	8.21	9.97	71.20	25.63	7.83
1998	4.77	47.44	20.66	5.45	12.10	86.40	31.10	9.50
1999	7.04	70.02	34.49	8.04	16.66	119.00	42.84	13.09
2000	5.04	50.16	21.84	5.76	8.20	58.60	21.10	6.44
Average 1991–2000	5.54	55.18	24.03	6.34	10.14	72.46	26.09	7.97

Table 7. Samplings of macroelements (kg.ha^{-1}) according to the dry mass yields of $N_{100}P_{40}K_{100}$ and $N_{200}P_{40}K_{100}$ variants in years 1991–2000

Years	$N_{100}P_{40}K_{100}$				$N_{200}P_{40}K_{100}$			
	P	K	Ca	Mg	P	K	Ca	Mg
1991	16.30	109.54	33.25	13.69	15.98	130.89	44.14	16.4
1992	9.45	63.50	19.28	7.94	8.30	67.94	22.91	8.69
1993	5.73	38.47	11.68	4.81	8.59	70.35	23.72	9.00
1994	8.90	59.81	18.16	7.48	7.85	64.33	21.69	8.23
1995	11.68	78.46	23.82	9.81	13.71	112.32	33.87	14.37
1996	11.55	77.62	23.56	9.70	10.50	86.00	29.00	11.00
1997	11.83	79.46	24.12	9.93	11.00	90.13	30.39	11.53
1998	14.53	97.61	29.63	12.20	12.33	100.96	34.05	12.91
1999	16.25	109.20	33.15	13.65	15.60	127.80	43.09	16.35
2000	9.18	61.66	18.72	7.71	9.09	74.48	25.11	9.53
Average 1991–2000	11.54	77.45	23.51	9.68	11.30	92.54	31.20	11.84

REFERENCES

Filipek-Mazur B., Mazur K. (1996): Dynamics of elements of mountain meadow sward quality in a static fertilizer experiment in Czarny Potok. Zesz. Probl. Post. Nauk Roln.: 51–60.

Firek E., Szewczyk W. (1996): Content of some nutrient elements in hay from a mountain meadow of the *Poa pratensis*/*Festuca pratensis* type. Zesz. Probl. Post. Nauk Roln.: 73–80.

Klapp E. (1971): Wiesen und Weiden. Paul Parey, Berlin, Hamburg.

Klesnil A., Benda J., Halva E., Petřík M., Štráfelda J., Turek F., Velebil M., Velich J. (1978): Intenzivní výroba píce. SZN, Praha.

Klimeš F. (1999): Fytocenologické vztahy v pastevních porostech. Rostl. Výr., *45*: 205–211.

Labuda J., Kacerovský O., Kováč M., Štěrba A. (1982): Výživa a krmenie hospodárskych zvierat. Príroda, Bratislava.

Míka V., Harazim J., Kalač P., Komárek P., Pavlů V., Pozdíšek J. (1997): Kvalita píce. ÚZPI, Praha.

Mrkvička J., Veselá M. (1997): Vývoj výnosů a botanického složení trvalých lučních porostů při absenci N-hnojení. Rostl. Výr., *43*: 565–570.

Mrkvička J., Veselá M. (1999): Druhová diverzita a výnosy psárkového porostu (*Alopecuretum*) při různém hnojení. Scientia Agric. Bohem., *30*: 95–105.

Mrkvička J., Veselá M. (2002): The influence of long-term fertilization on species diversity and yield potential of permanent meadow stand. Rostl. Výr., *48*: 69–75.

Rychnovská M., Balátová-Tuláčková E., Úlehlová B., Pelikán J. (1985): Ekologie lučních porostů. Academia, Praha.

Veselá M., Mrkvička J. (1997): The effect of soil water regime on vigour of species of permanent grasslands. Scientia Agric. Bohem., *28*: 161–170.

Received on April 29, 2002

ABSTRAKT

Druhové složení, kvalita a výnosy luční píce při různém hnojení

V lučním pokusu byly v letech 1991–2000 sledovány čtyři varianty: kontrolní (bez hnojení), 40 kg P + 100 kg K.ha^{-1}, 100 kg N.ha^{-1} (+ PK) a 200 kg N.ha^{-1} (+ PK). Zastoupení jednotlivých agrobotanických skupin a druhů bylo zjišťováno metodou redukované projektivní dominance (D v %) před sklizní první seče. Sklizená zelená hmota byla na místě vážena a odebrané vzorky pro stanovení sušiny byly použity pro chemické analýzy. Největší změny v proměnlivosti porostové skladby jsme zaznamenali u kontrolní varianty. Výnosy suché hmoty v průběhu deseti let kolísaly u kontrolní varianty v rozmezí 1,07–3,42 t.ha^{-1}, u plochy hnojené $P_{40}K_{100}$ v rozmezí 2,09–5,95 t.ha^{-1}, u ploch s dusíkatým hnojením (+ PK) v rozmezí 2,29–6,52 t.ha^{-1}, resp. 3,74–7,61 t.ha^{-1}. Podle *t*-testu jsou výnosy suché hmoty jednotlivých variant v období sledování průkazné na hladině významnosti 95 %.

Klíčová slova: trvalý luční porost; hnojení; druhová pestrost; výnosy; obsahy prvků

Corresponding author:

Doc. Ing. Jiří Mrkvička, CSc., Česká zemědělská univerzita v Praze, 165 21 Praha 6-Suchdol, Česká republika,
tel.: + 420 224 383 036, fax: + 420 220 921 369, e-mail: mrkvicka@af.czu.cz