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CONTENTS — Grassland

REVIEW

OBSAH — Travní porosty

Production and ecological functions of grassland in landscape

The 13th General Meeting of the European Grassland Federation to be held in June 1990 at Banská Bystrica will discuss the soil — grassland — animal relationship, as its main subject. The main reports and the papers by the participants, both Czechoslovak and from other countries, all refer to this subject. Following up with this scientific session, this topical issue of the magazine Rostlinná výroba now appears as an additional survey of the activity and results of grassland research mainly in the Czech Socialist Republic. It should be stressed in this context that over the past ten years our grassland research has been focused on both the agro-economic and environmental aspects of the problems studied, in order to avoid greater damage that might be caused by the proposed technologies of grassland improvement and intensification to the important non-production functions of grassland in the landscape. Czechoslovakia is among the countries with a small area of agricultural land (0.43 ha) and arable land (0.30 ha) per capita of population, so we must handle our land fund with utmost care, making use of all its functions in the landscape and preventing any decrease in its productivity.

In Czechoslovakia, grasslands cover 24.4 % of all farm land. Their real production and economic role still remains at an about 50% level because a large proportion of these sites are located on steep slopes (about 25 % of the area on slopes above 15°) and because the fertility of their soils is low, including extreme moisture conditions, high acidity, deficit of some nutrients. However, at the same time, grassland, together with forests, is the most important stabilizing factor of the landscape in Czechoslovak conditions. This function of grassland should by no means be weakened: it should be utilized rationally within the complex of reclamation, intensification and exploitation practices. The increased content of organic matter in the soils under grassland, the perennial nature and long growing season of the stands provide them with a high degree of self-regulation of the environmental processes and a capability to offset, to some extent, the adverse effects to which the soil and plants are exposed. Grassland is an important factor of erosion control on hillsides and in inundation areas. Its high retention capacity protects the surface and underground waters against pollution with nitrates. Grassland is also an important hygienic and aesthetic feature in the landscape and may also be a source of important or protected flora. Meadows and pastures produce large amounts of nutrients and energy for ruminants and are an important ecosystem whose varied species composition contributes significantly to the nature of the landscape and to its stability.

Drainage of waterlogged meadows and pastures is frequently an object of argument between ecologists, hydrologists and agronomists. Ecologists often consider the drainage of waterlogged grassland as unnecessary or even harmful. They recommend that waterlogging should be removed only through the so-called biological drainage, i. e. increased evapotranspiration of the fertilized stands. However, research results suggest that increased water output from the plants (30 to 100 mm annually) usually fails to offset the flow of water from the springs and the high water table. Therefore it is necessary in the majority of cases to combine biological and technical means. Unfortunately, intensive drainage of grassland often led to permanent reclamation which in turn caused an increased erosion and eutrophication of water in the watersheds. Under Czechoslovak conditions, any unnecessary drainage is a loss, both financial and environmental. Good hydrological and environmental possibilities are offered by the newly developed system of regulation drainage.

Permanent grasslands have a substantial enviromental mission not only as possible sites of occurrence of rare plants but also for the high nitrate retention capacity of the sward. There is clear experimental evidence that the nitrate content in the infiltrated water under permanent sward is much lower than under the sward of temporary grassland. The high erosion control capacity of permanent grassland is also very important. However, permanent grassland does not provide very high herbage output and fails to accept a larger proportion of clovers with the high activity of their rhizobial bacteria which would save nitrogen fertilizers. A significant contribution from the agroeconomic and ecological point of view is offered by the developing technology of no-tillage overseeding into the sward.

Full and well-balanced nutrition, together with an adequate water regime, is a major factor underlying the production of grass biomass and the production of nutrients. Nitrogen is a key nutrient which has the highest production efficiency in

Czechoslovak conditions; however, nitrogen may have some adverse effects on the environment and landscape. As a rule, an increased nitrogen application rate leads to a considerable reduction of the species diversity of the stand and the content of nitrates in the herbage may exceed the tolerable level. Nitrogen application rates must therefore be optimized with respect to the given environmental conditions and the technique of application of fertilizers has to be refined. In this association, it should be stressed again that grassland sward has a high (but not extreme) nitrate retention capacity. It is very important, as indicated by research results, that nitrogen losses under intensively fertilized grasslands were the same as, or lower than, under unfertilized and unexploited grasslands. High importance is also attached to the recommendation to use biological sources (especially some varieties of white clover and red clover) to meet the high nitrogen requirement of grassland. Although such an orientation of grassland management is more exacting from the agronomic point of view, it provides in some cases the best economic results, saves energy, and is most acceptable for the environment.

Systems of grassland improvement and intensification lead, with their consequences, to an equalization of the water, air and nutrient regime which is most suitable to the cultivated mesophytic plant and animal species. Species of hygrophytic and oligotrophic type disappear from the landscape. In each particular case, due attention should be paid to the priorities of the production or non-production functions of the sites in the landscape and watershed, and the method and intensity of exploitation should be determined on this basis. If the approaches are differentiated like this, it will be possible to maintain some diversity of the meadow sites and grass stands and to prevent them from equalization. However, rational solutions require thorough knowledge of the theoretical problems and detailed familiarization with the features of the given site and landscape.

In close association with the above-mentioned problems, solutions are being sought to the problems of herbage quality, nutrient concentration and energy content; all this is important for efficient nutrient and energy conversion in ruminant nutrition. It is necessary to employ all the known and technically available practices, including grazing, to achieve a substantial reduction of losses in the process of herbage production and utilization. The effectiveness of fertilization should be evaluated not only quantitavely but also with an increased emphasis on quality. This applies to nitrate content as well as to the concentration of potassium in herbage, to its ratio to other cations, to the presence of a number of nutritionally defective substances etc. The proportion of clovers and herbs is of substantial importance for the quality of herbage and for its intake by animals. Increased attention should be paid to the methods of preservation of meadow and pasture herbage which are decisive for its resultant quality. We are aware that good-quality and hygienically safe forage is an important link in the food chain for human nutrition.

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EVAPOTRANSPIRATION FROM GRASSLAND AND ITS RELATION TO THE GROUNDWATER TABLE

P. Klímová, D. Haken, T. Kvítek

KLÍMOVÁ, P. — HAKEN, D. — KVÍTEK, T. (Research Institute for Soil Improvement, Praha): *Evapotranspiration from grassland and its relation to the groundwater table.* Rostl. Výr., *36*, 1990 (5) : 451-462.

A five-year trial was conducted at Uhříněves with compensating lysimeters [groundwater table (GWT) at a depth of 70 cm (1984, 1985), at 55 cm (1986, 1987) and at 50 cm (1988), with disturbed medium-heavy, loamy, gray-brown podzolic soil] to study the effect of the depth GWT on evapotranspiration (ET) in grassland and on water supply from GWT through capillary elevation, representing a component of ET balance. The average ET for the growing season was 433, 447 and 494 mm at GWT depths of 70, 55 and 50 cm and the average values of water supply through capillary elevation from GWT at the given depths were 20.8, 33.5 and 112.6 mm. The differences in the amount of capillary water at three values of GWT are statistically significant, while the differences in ET do not differ significantly. A statistically significant relationship was observed between air saturation deficit (Sd) and ET at each depth of GWT observed. Between the air Sd and the amount of capillary water from GWT, there was a close correlation at a GWT of 50 cm and 70 cm. A close correlation is observed between the amount of water supplied from GWT and potential ET (Penman, at a GWT of 50 cm, 55 cm) and a comparatively less close correlation to actual ET (dependence found only at GWT 50 cm).

grassland; lysimetric trials; groundwater table; evapotranspiration; capillary supply from groundwater table

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Optimum conditions of groundwater table (GWT) for the growth of grasslands are provided when the imbibing capillary margin lying above GWT reaches the root zone in the growing season without permanent waterlogging (Turek quot. by Klesnil, 1982) and when the maximum height of GWT supplies this zone with 5 mm of water daily (Haken, 1976; Brandyk, Wesseling, 1985).

GWT should be stabilized at an adequate depth under the soil surface: in meadows it is 0.5—0.6 m or 0.4—0.7 m in the growing season, lower value applying to lighter-textured soils, higher ones to heavier-textured soils (Jůva et al., 1973; Klesnil, 1982).

As stated in the standard ON 75 4202 (1987), the admissible lowest GWT depths under soil surface (h_{min}), which are 0.25—0.4 m for meadows, are decisive for evaluation of suitable levels of GWT. The GWT is ascertained from the relationship of the value representing the depth of the drain and the h_{min} value. The optimum depth of GWT for permanent grasslands is given by the standard for loamy soil to be 0.70—0.85 m. The values of GWT above optimum for the grassland testify to the priority of sod bearing capacity. The requirement for bearing capacity is limited by optimum height from the viewpoint of the stand and brings about a need to optimize water regime as related to other factors of the site (Haken, 1976; Kvítek, 1985).

GWT affects the rate of evapotranspiration (ET) through the supply of water into active soil profile. When determining ET by water balance (by the lysimetric method) the amount of capillary water from GWT can be investigated as one of the components of water balance.

The importance of three different depths of GWT for the ET of the grassland is studied in this paper from the viewpoint of water supplied from GWT and its utilization in ET, and the data are evaluated in relation to weather conditions as one of the decisive factors of the significance of GWT for ET.

MATERIALS AND METHODS

The trial was performed at Uhříněves (1984 — 1988) at an altitude of 295 m above sea level; the climatic region is mild and warm, subregion B_2 — moderately warm with prevailing warm winter. The normal of precipitation is 575 mm, temperature normal 8.3 °C (380 mm and 14.6 °C, in the growing season). Precipitation was recorded directly at the site, the values of air temperatures were taken from the Czech Hydrometeorological Institute at Uhříněves.

Evapotranspiration (ET) was determined volumetrically by five compensatory lysimeters (type according to Thorntwait, P = 4 sq m, depth 0.8 m) filled up to the soil surface. The lysimeters are filled with soil from the site (in 1981). The groundwater table (GWT) is kept constant: in 1984 and 1985 at 70 cm, in 1986 and 1987, at 55 cm and in 1986 at 50 cm. The measurements were carried out in the growing season.

Characteristics of soil layer 0—30 cm: brown earth, loamy soil, medium-heavy-textured soil (content of clayey particles 34—38 %, content of category II 43—50 %), porosity 49—55 %, specific weight 2.66 g per cubic cm, good reserve of available nutrients (phosphorus 120—160, potassium 90—130 and magnesium 100—120 mg per kg); the soil is sorptively saturated, humus content is medium (1.2—1.7 % C_{ox} content of total nitrogen is 0.18—0.19 %. The soil-forming substrate is composed of loess loams.

The lysimeters differed in nitrogen application rates (gradated application at rates of 0, 50, 100, 200 and 300 kg per ha); PK-fertilization was the same in all lysimeters: 44 P and 133 K (1984 and 1985), 60 K (1986 and 1987), 100 K (1988) in kg per ha. PK was applied in autumn, application of N was divided: 45 % at the beginning of the growing season, 35 % after the first cut and 20 % after the second cut. All fertilization treatments are evaluated aggregatively.

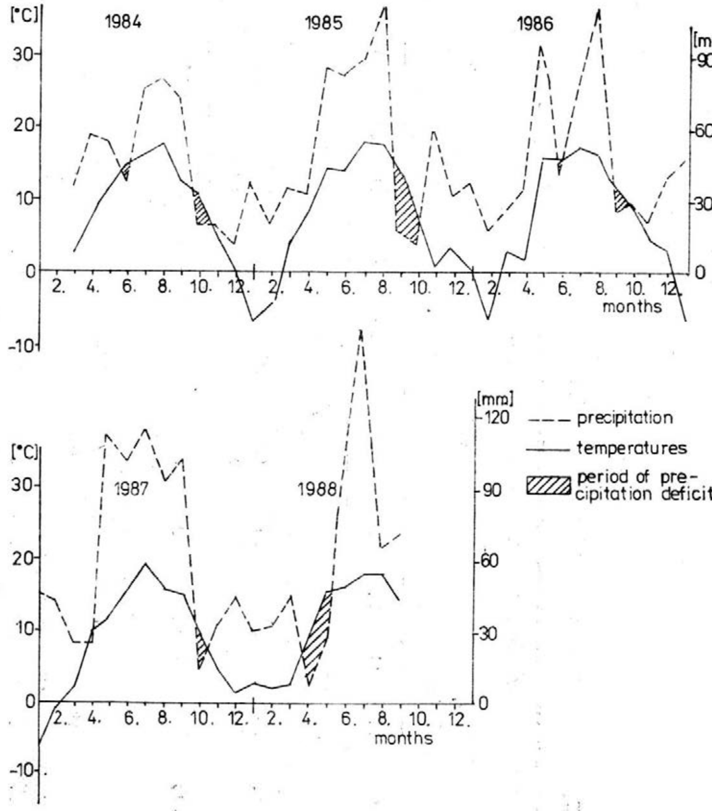
Lysimeters were sown with grass mixture (August 31, 1983) consisting of meadow fescue (*Festuca pratensis* HUDS.), timothy (*Phleum pratense* L.) and smooth-stalked meadow grass (*Poa pratensis* L.) at sowing rates of 12, 10 and 8 kg per ha, respectively. Values of ET (i. e. actual ET) for each period of sowing and for the whole growing season were determined on the basis of the water balance:

$$ET = S + Z - O + \Delta W \text{ [mm]},$$

the separate balance components being precipitation (S), water infiltration from active soil profile up to the level of GWT (O), increase or decrease of water from water reserve (ΔW) and water supplied by capillary elevation from GWT into the active soil profile (Z). The determination of potential ET (ETP) is carried out after Penman.

Analysis of variance was used in testing the significance of differences between ET at different GWT's. Test after Scheffe and method of multiple comparison were used to offset the lack of balance in the model and the non-homogeneity of dispersion. Regression analysis was used for evaluation of the relationship of ET values to weather.

1. The course of temperatures and precipitation over the years 1984 to 1988



RESULTS AND DISCUSSION

Weather conditions, evapotranspiration in grassland

From the viewpoint of requirement of grassland for weather, the years 1984 and 1985 were comparatively favourable, 1987 was very favourable, and 1986 and 1988 were unfavourable (a period with rainfall deficit at high temperatures) (Fig. 1). The highest consumption of water for evapotranspiration per yield unit (transpiration coefficient = 606, 589, respectively), and at the same time the highest values of relative deficit of evapotranspiration (1 — actual ET/potential ET) were recorded in 1986 and 1988.

The average value of ET for the growing season was 451 mm in the five years of trials and the average ETP (potential ET, Penman; was not recorded in 1984) was 474 mm; the average daily ET was 2.50 mm for the whole period (Tab. I), and the ETP was 2.71 mm. The lowest total ET's and the lowest average daily ET's were recorded in 1984 (the first production year, GWT 70 cm). The highest values were in 1988 (GWT 50 cm). The average ET for the growing season was 433 mm at GWT 70 cm, 447 mm, at GWT 55 cm, and 494 mm at GWT 50 cm.

The values of ET and its components were influenced simultaneously by weather along with the effect of stands-giving different yields (the differences were caused by weather in the separate years and by the year-to-year variation of the stand) and, finally, by the GWT. With the available set of data, the effect of different GWT's on the stand

I. Weather data, evapotranspiration (ET) and capillary water supplied from GWT and used for ET

Summary values for the periods of separate cuts and for the whole growing season of grassland

GWT (cm)	70 1984			70 1985			55 1986			55 1987			50 1988		
Cuts	I	II	III + IV	I	II	III + IV	I	II	III + IV	I	II	III + IV	I	II	III + IV
	I–IV			I–III			I–III			I–IV			I–III		
Precipitation (mm)	111	100 420	209	107	165 418	146	81	144 386	161	112	175 537	250	33	197 408	178
Air temperature (°C)	588	791 2730	1352	652	895 2935	1387	603	937 2674	1134	564	770 2628	1295	668	830 2603	1105
Saturation deficit of air (KPa)	24	28 93	41	27	31 99	41	25	36 100	38	24	22 80	34	33	23 93	37
Potential ET (mm)	—	— —	—	126	178 480	176	125	198 488	166	119	147 462	196	152	152 469	165
Actual ET (mm)	119	108 397	170	117	171 469	181	126	169 440	145	109	144 455	201	127	172 494	195
Capillary water supplied from GWT and used for ET (mm)	2.7	16.2 24.2	5.3	1.4	2.3 17.5	13.8	7.7	34.4 65.2	23.1	0.7	2.6 13.8	10.5	56.2	23.7 112.6	32.7
Yield (dry matter in t per ha)	1.94	3.37 8.36	3.05	3.71	5.15 11.24	2.38	2.80	2.02 7.26	2.44	3.48	4.39 10.92	3.05	2.69	3.28 8.38	2.41

Average daily values in the periods of cuts and for the whole growing season															
GWT (cm)	70 1984			70 1985			55 1689			55 1987			50 1988		
Cuts	I	II	III + IV	I	II	III + IV	I	II	III + IV	I	II	III + IV	I	II	III + IV
	I–IV			I–III			I–III			I–IV			I–III		
Precipitation (mm)	1.95	1.96	2.22	1.87	2.88	2.12	2.20	2.49	2.11	2.19	3.73	3.13	0.63	3.94	2.74
		2.08			2.28			2.26			3.02			2.44	
Air temperature (°C)	10.3	15.5	14.4	11.4	15.7	20.1	16.3	16.2	14.9	11.0	16.4	16.2	12.9	16.6	17.0
		13.5			16.0			15.6			14.7			15.6	
Saturation deficit of air (kPa)	0.41	0.55	0.44	0.47	0.55	0.59	0.68	0.63	0.50	0.47	0.47	0.43	0.64	0.47	0.57
		0.46			0.54			0.58			0.45			0.56	
Potential ET (mm)	–	–	–	2.21	3.12	2.55	3.38	3.41	2.18	2.33	3.13	2.45	2.92	3.04	2.55
		–			2.62			2.85			2.60			2.81	
Actual ET (mm)	2.09	2.12	1.81	2.05	3.00	2.62	3.40	2.91	1.91	2.14	3.06	2.51	2.44	3.44	3.00
		1.96			2.56			2.57			2.56			2.96	
Capillary water supplied from GWT and used for ET (mm)	0.05	0.32	0.06	0.02	0.04	0.20	0.21	0.59	0.30	0.01	0.06	0.13	1.08	0.47	0.50
		0.12			0.10			0.38			0.08			0.67	

cannot be clearly confirmed from the values of ET (neither from the yield, nor from the effectiveness of water). The differences between ET values at GWT 70, 55 and 50 cm are not statistically significant with respect to the non-homogeneity of dispersion. Insignificant differences were found in the periods of the first and second cuts. A significant difference ($\alpha = 0.01$) in ET between GWT at 50 cm and the remaining GWT's at 55 and 70 cm was recorded only at the third cuts.

Water supply from GWT through capillarity into the active soil layer

The significance of the GWT is, therefore, evaluated on the basis of one of the components of ET balance, using the amount of water added through capillarity from GWT into the active soil profile of 5 to 40 cm where this water is used for ET. The amount of capillary water was low in each year, except 1988 at a GWT of 50 cm; however, water supply was not sufficient in the period of higher requirements of the stand for water even at a GWT of 50 cm.

Water supply through elevation is differentiated by GWT: at a GWT of 70 cm the total values for the whole growing season were 24.2 and 17.5 mm (1984, 1985, respectively), at a GWT of 55 cm 65.2 and 13.8 mm (1986 and the wet year 1987) and at a GWT of 50 cm — 112.6 mm. With GWT at 70 cm, the proportion of this water was 6 and 3.7 %, at 55 cm — 14.8 and 3 %, and at 50 cm — 22.8 % of the total value of ET.

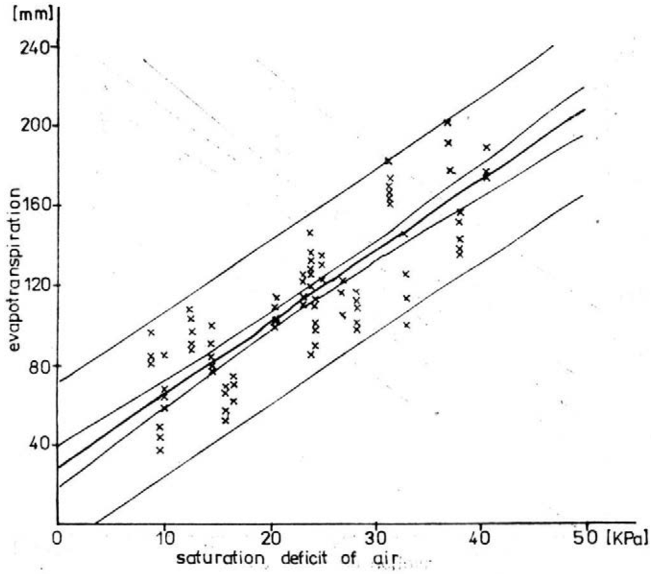
The obtained values of water supply from GWT were low, as compared with data in literature (lysimetric trials with grasslands). According to Gavenčiak (1976), the ET of grassland (loamy soil) at a GWT of 0.7 m was 574 mm, at GWT 0.4 m 627 mm; the maximum average daily ET in a month period was 4.3 mm (both at a GWT of 40 cm, and at a GWT of 70 cm in another period). The average daily water supply from GWT over the growing season was 0.7 m — 1.2 mm (10 times higher than our value) at a GWT of 0.7 m: at a GWT 0.4 m it was 1.6 mm (2.4 times higher). Mundel (1982) reports wide ranges of average daily values of ET: 1.5—5 and 2.5—9 mm, at a GWT of 0.4 m ET 11 to 14 mm. Korotkov (1987) found out that the total water supply for the growing season in soddy podzolic soil at a GWT of 0.75 m was 62 mm and ET 395 mm; at a GWT of 1.5 m the water supply was 8.5 mm and ET was 354 mm; the proportion of added water out of the total ET in this case was 15.7 and 2.4 %. Consumption of water from GWT in peat bog soil was 70—80 % out of the total ET value at GWT's of 0.4 to 1.0 m (Panov, Shiskov, 1974).

Significance of differences in water supply from GWT

Differences in the amount of capillary water from the three GWT's studied are statistically highly significant ($\alpha = 0.01$). Evaluating all cuts in total, it was even in the first and second cuts that GWT at 50 cm highly significantly differed from GWT's at 55 and 70 cm in having a much higher water supply to the active layer. When the extraordinary year 1987 is eliminated from the set of values, the difference between GWT 50 and GWT 55 cm loses its significance; only GWT of 70 cm ($\alpha = 0.01$) is significantly different with its lower water supply, from the mentioned GWT's.

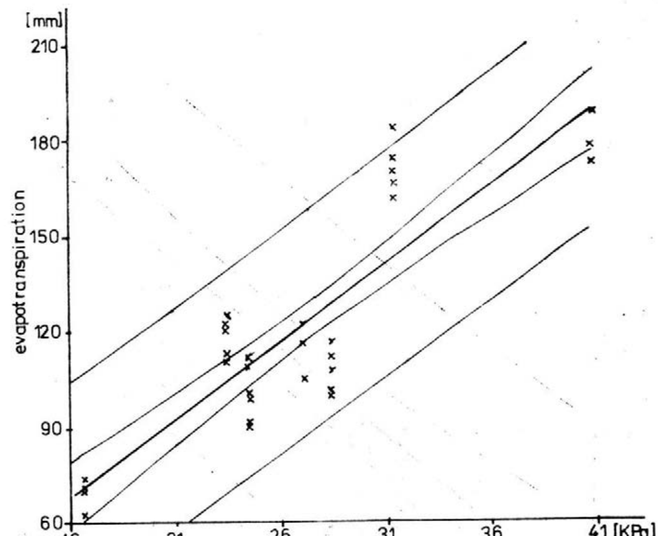
Analysis of the relationship between ET and saturation deficit (Sd) of air

A significant close correlation between the two values was found out on the basis of statistical analysis of ET and Sd of air by simple regression. A functional dependence of the total values for the balanced periods of the separate cuts was determined at each level of GWT (except the statistical insignificance of the constant at a GWT of 70 cm), and the same dependence was observed in general evaluation for the whole period of study (Fig. 2 to 5).



GWT at 70, 55 and 50 cm in total
ET = 29.854 + 3.560 $Sd_{(KPa)}$ mm
$r = 0.8583^{++}$
$R^2 = 73.67$ %

2. The dependence of grassland ET on the air Sd at the different groundwater table (GWT) in the balance periods of cuts

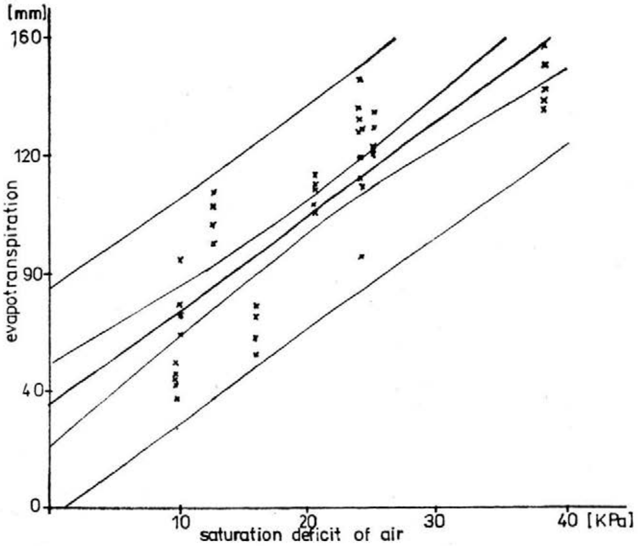


GWT at 70 cm, 1984 and 1985
ET = −8.832 + 4.833 $Sd_{(KPa)}$ mm
$r = 0.8994^{++}$
$R^2 = 80.88$ %

3. The dependence of grassland ET on the air Sd at the different groundwater table (GWT) in the balance periods of cuts

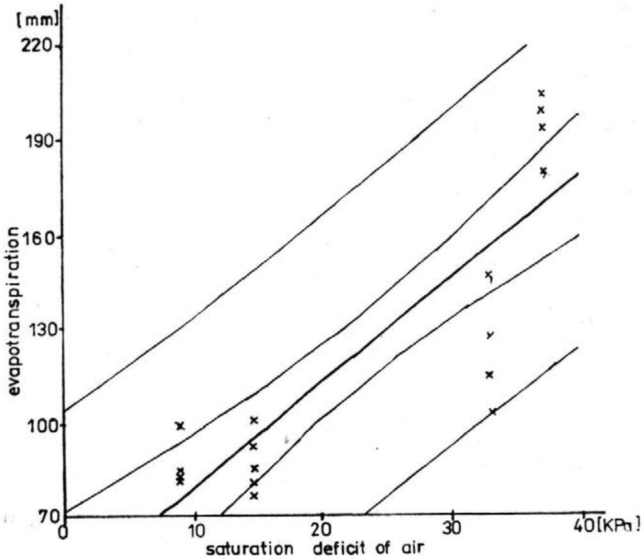
The Sd of air is considered as a simple climatic factor with close relationship to the ET of grassland (Sláma, 1980; Mundel, 1982; Renger, 1984).

A close correlation of ET and Sd was recorded at each level of GWT; the variability of water consumption for ET can be explained, to an extent of 70—81 %, by the variability of air Sd, using the coefficient of determination (R^2). Comparatively higher values of correlation coefficient (r) and R^2 were found at a GWT of 70 cm.



GWT at 55 cm, 1986 and 1987
ET = 34.990 + 3.220 Sd(KPa) mm
$r = 0.8382^{++}$
$R^2 = 70.26$ %

4. The dependence of grassland ET on the air Sd at the different groundwater table (GWT) in the balance periods of cuts



GWT at 50 cm, 1988
ET = 46.109 + 3.306 Sd(KPa) mm
$r = 0.8635^{++}$
$R^2 = 74.57$ %

5. The depedence of grasland ET on the air Sd at the different groundwater table (GWT) in the balance periods of cuts

Analysis of the relationship between water elevation from GWT and Sd of air

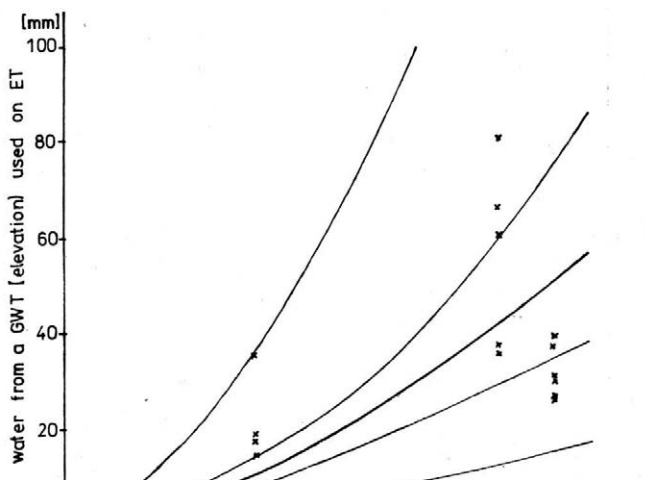
The amount of water brought by capillary elevation from GWT to active soil profile and utilized for ET was statistically tested in relationship to the Sd of air, to the temperature of air, precipitation, ET actual and ET potential.

At a GWT of 50 cm, the power function was the most suitable for the evaluated relationship of the amount of added water to the Sd of air, which was statistically highly significant ($r = 0.8807^{++}$, $R^2 = 77.5$ %, Fig. 6). The linear function ($r = 0.5817$, $R^2 = 33.8$) was the best at a GWT of 70 cm. The regression coefficient is significant at a GWT of 55 cm but the constant is not significant.

Evaluating the addition of water by elevation in relation to air temperature, it is found out that the regression coefficient is significant at each level of GWT and the constant is insignificant (the highest correlation was determined at a GWT of 70 cm).

No relationship was ascertained between water supplied from GWT and the precipitation.

The effect of weather expressed by the Sd of air is in a direct relation also to the amount of water supplied from GWT into the active soil layer at GWT's of 70 and 50 cm. An important difference consists in the fact that water supply from GWT, according to the coefficient of determination can be explained at a rate of 77 % by the effect of air Sd at a GWT of 50cm, whereas at a GWT of 70 cm only 33.8 % of the water supply from GWT can be ascribed to the effect of air Sd. A significantly higher proportion of other factors of the site, besides the effect of air Sd, is therefore involved in water supply from a GWT of 70 cm, in comparison with water supply from GWT at a depth 50 cm. The independence of the values of Sd and water supply at a GWT of 55 cm can be explained by the low and sporadically occurring values of water supplied in the wet year 1987.

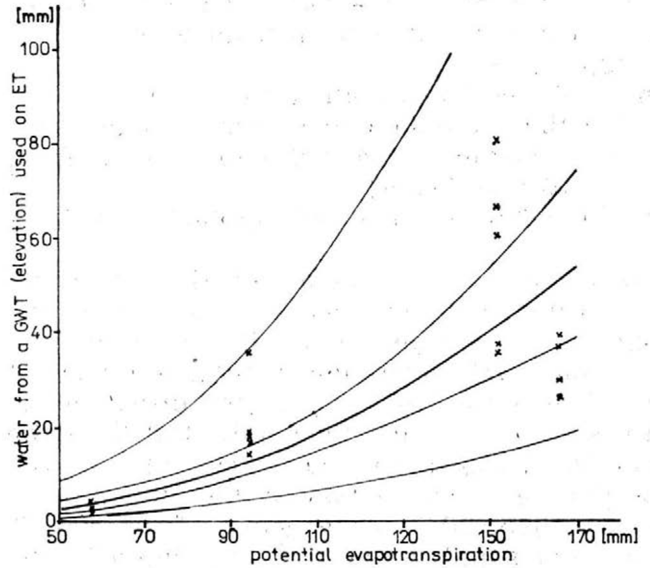


$y = 0.12191 \cdot x^{1.6662}$
$r = 0.8807^{++}$
$R^2 = 77.56$ %

6. The dependence of water elevation from a GWT at 50 cm to active soil layer on air Sd

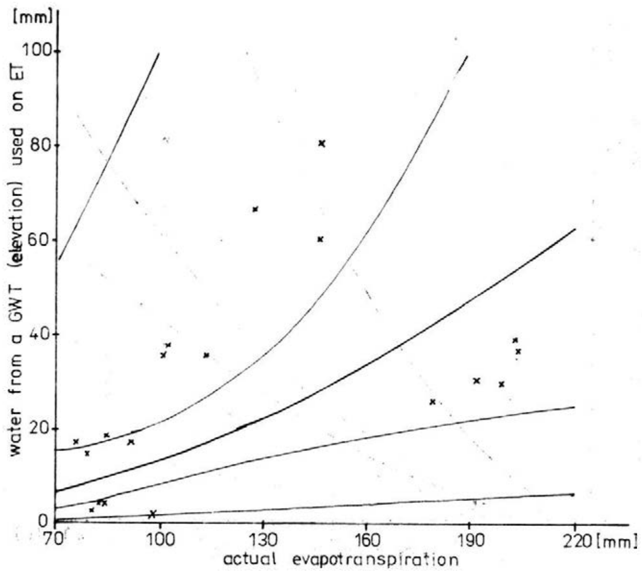
Testing of the rate of dependence between the amount of water elevated from GWT and evapotranspiration brought these results:

— statistically significant close correlation was determined at a GWT of 50 cm ($r = 0.9126^{++}$, $R^2 = 83.3$ %, Fig. 7) and at a GWT of 55 cm (linear model, $r = 0.5446^{+}$, $R^2 = 29.6$ %) in evaluation of the relationship between supplied water and potential ET;



$y = 1.9220 . 10^{-4} . x^{2.4421}$
$r = 0,9127^{++}$
$R^2 = 83.3$ %

7. The dependence of water elevation from GWT at 50 cm to active soil layer on potential ET (1988)



$y = 1.5606 . 10^{-3} . x^{1.9662}$
$r = 0.6153^{+}$
$R^3 = 37.86$ %

8. The dependence of water elevation from GWT at 50 cm to active soil layer on actual ET (1988)

— the closeness of this correlation declined markedly and is significant only at a GWT of 50 cm [$r = 0.6153^{+}$, $R^2 = 37.8$ %, Fig. 8] when evaluating the relationship between the amount of supplied water and actual evapotranspiration.

Differences between separate depths of GWT are confirmed by these results, namely the differences between GWT's of 50 cm and 55 cm which are expressed by the different relationships between capillary elevation values and actual ET at the given GWT's.

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KLÍMOVÁ, P. — HAKEN, D. — KVÍTEK, T. (Výzkumný ústav pro zúrodnění zemědělských půd, Praha): *Evapotranspirace travního porostu a její vztah k úrovni hladiny podzemní vody.* Rostl. Výr., *36*, 1990 (5) : 451-462.

V rámci pětiletého pokusu v Uhříněvsi s kompenzačními lyzimetry [hladina podzemní vody (HPV) v 70 cm (1984, 1985), v 55 cm (1986, 1987) a v 50 cm (1988), s porušenou zeminou — středně těžká, hlinitá hnědozem] byl sledován vliv hloubky HPV na evapotranspiraci (ET) travního porostu a na dotaci vody z HPV kapilárním vzlínáním, představujícím bilanční složku ET. Průměrná ET za vegetaci činila při HPV 70, 55 a 50 cm 433, 447 a 494 m, průměrné hodnoty dotace vody kapilárním vzlínáním z HPV byly při uvedených hloubkách 20,8; 33,5 a 112,6 mm. Rozdíly v množství kapilárně doplňované vody u tří sledovaných HPV jsou statisticky průkazné, zatímco rozdíly v ET se průkazně neliší. Statisticky významný vztah byl zjištěn mezi sytostním doplňkem (Sd) vzduchu a ET, a to při všech sledovaných hloubkách HPV. Mezi Sd vzduchu a množstvím kapilárně doplňované vody z HPV byl těsný vztah při HPV 50 cm, resp. při HPV 70 cm. Množství doplňované vody z HPV je v těsném vztahu k ET potenciální (Penman, při HPV 50 cm, resp. HPV 55 cm) a relativně v méně těsném vztahu k ET aktuální (závislost zjištěna jen při HPV 50 cm).

travní porosty; lyzimetrické pokusy; hladina podzemní vody; evapotranspirace; kapilární doplňování z hladiny podzemní vody

КЛИМОВА, П. — ГАКЕН, Д. — КВИТЕК, Т. (Научно-исследовательский институт по освоению сельскохозяйственных земель, Прага): **Эвапотранспирация травостоев и ее отношение к уровню подземных вод.** Rostl. Výr., *36*, 1990 (5) : 451-462.

В рамках пятилетнего исследования в Угржиневси компенсационных лизиметров [уровень подземной воды (УПВ) в 70 см (1984, 1985 гг.) в 55 см (1986, 1987 гг.) и в 50 см (1988 г.), с нарушенным грунтом — средне тяжелым, илисто бурым] исследовали влияние глубины УПВ на эвапотранспирацию (ЭТ) травостоев и на дотацию воды из УПВ капиллярным поднятием, представляющим балансовую составную ЭТ. Средняя ЭТ в период вегетации составляла при УПВ 70, 55 и 50 см 433, 447 и 494 мм, средние величины дотации воды капиллярным поднятием из УПВ на приведенных глубинах составляли 20,8; 33,5; 112,6 мм. Различия в количестве капиллярно дополняемой воды у трех исследуемых УПВ являются статистически достоверными, затем как различия в ЭТ достоверно не различаются. Статистически существенное отношение было установлено между насыщенном добавлении (НД) воздуха и ЭТ, а именно у всех исследуемых глубинах УПВ. Между НД воздуха и количеством капиллярного добавления воды из УПВ было тесное соотношение при УПВ 50 см, или при УПВ 70 см. Количество добавляемой воды из УПВ находится в тесном соотношении с ЭТ потенциально (Пенман, при УПВ 50 см, или УПВ 55 см) и относительно в менее тесном соотношении с ЭТ актуально (зависимость обеспечена лишь при УПВ 50 см).

травостои; лизиметрические исследования; уровень подземной воды; эвапотранспирация; капиллярное дополнение из уровня подземной воды

KLÍMOVÁ, P. — HAKEN, D. — KVÍTEK, T. (Forschungsinstitut für Bodenfruchtbarkeit, Praha): *Evapotranspiration der Grasdecke und ihre Beziehung zum Grundwasserspiegel.* Rostl. Výr., *36*, 1990 (5) : 451-462.

Im Rahmen eines fünfjährigen Versuchs mit Kompensations-Lysimetern in Uhříněves [Grundwasserspiegel (weiter HPV) in 70 cm (1984, 1985), in 55 cm (1986, 1987) und in 50 cm (1988), mit gestörtem Bodensubstrat — mittelschwere lehmige Braunerde] wurde der Einfluß der Tiefe des HPV auf die Evapotranspiration (ET) der Grasdecke und auf die Wasserdotation aus dem HPV durch Kapillaraszension, die eine Bilanzkomponente der ET darstellt, untersucht. Die mittlere ET während der Vegetationsperiode betrug bei HPV 70, 55 und 50 cm 433, 447 und 494 mm, die Mittelwerte der Wasserdodation durch Kapillarasension aus HPV bei den angeführten Tiefen waren 20,8; 33,5 und 112,6 mm. Die Unterschiede der Menge des kapillar ergänzten Wassers bei den drei untersuchten HPV sind statistisch signifikant, während die Unterschiede in der ET unsignifikant sind. Eine statistisch signifikante Beziehung wurde zwischen dem Sättigkeitssupplement (Sd) der Luft und der ET festgestellt und dies bei allen untersuchten Tiefen des HPV. Zwischen Sd der Luft und der Menge des kapillar ergänzten Wassers aus HPV bestand eine enge Beziehung bei HPV 50 cm bzw. bei HPV 70 cm. Die Menge des ergänzten Wassers aus HPV steht in enger Beziehung zur potentiellen ET (Penman, bei HPV 50 cm bzw. 55 cm) und in relativ weniger enger Beziehung zur aktuellen ET (Abhängigkeit nur bei HPV 50 cm nachzuwesien).

Grasbestand; lysimetrische Versuche; Grundwasserspiegel; Evapotranspiration; kapillare Ergänzung aus dem Grundwasserspiegel

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NITROGEN CIRCULATION IN THE GRASSLAND ECOSYSTEM TREATED WITH DIFFERENT FERTILIZER RATES

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VELICH, J. — MRKVIČKA, J. — BĚLOHOUBEK, A. (University of Agriculture, Praha): *Nitrogen circulation in the grassland ecosystem treated with different fertilizer rates.* Rostl. Výr., *36*, 1990 (5) : 463-470.

Data on the amount, distribution and some conversions of nitrogen were determined in six permanent meadows of mesophytic type in the potato growing region [annual precipitation of 536—641 mm, temperatures 7—7.8 °C average; groundwater table 0.45—0.60 m under the surface; C_{ox} content in the soil layer of 0—0.2 m: 2.3—4.2 %, C/N ratio 5—17, pH (KCl) 4.5—6.3] in the 11th to 17th year of using the fertilization scheme of 0—PK—N_{100}PK—N_{200}PK—N_{300}PK—N_{400} PK (index = kg N per ha). The changes in the contents of C_{ox} and N_t, in the percolation of nutrients into groungwater, in the species composition of the phytocoenoses and in their yields suggest that the meadow ecosystems were comparatively stabilized. A slightly decreased level of soil N_t stabilized under favourable conditions for mineralization of soil organic matter at application rates of $N_{200-400}$PK, and particularly at PK-fertilization alone, and the reverse was the case under less favourable conditions. Fertilization raised the N_{min} proportion of N_t from 1.7 % in unfertilized soil to 2—2.7 % in fertilization treatments of PK alone up to N_{400}PK. Out of the total N_{org} in the soil, the following proportions were subject to annual mineralization (in the same order as the respective fertilizer rates): 3.4—4.7—3.1—3.6—4.1—4 %. The intensity of nitrogen flows in the soil was the highest with PK-fertilization. The average proportions of the rates of 100—200—300—400 kg of nitrogen per ha recovered through increased yields were 48—50—45—40 %. Denitrification (16—58—122——198 kg per ha) accounts for a prevailing proportion in nitrogen losses from the ecosystem of permanent meadows, resulting in a lower nitrate leaching in comparison with temporary grasslands and especially with arable land.

grassland; permanent meadows; fertilization; nitrogen circulation

The main pathways of the circulation of nitrogen which is the key nutrient in meadow ecosystem are generally well known. Data on the separate components of nitrogen circulation and on the factors that influence it are given in many studies. Whitehead (1970), Lazemby (1981) and others give an over-all survey of these studies. However, N circulation and the associated processes can still be quantified only approximately, owing to some methodical problems of measurement of some its component under natural conditions. Under various conditions, plenty of objective data have been gathered, concerning the recovery of applied nitrogen through forage harvest or through the production of grazing animals, and there is also a comparatively large body of data on nitrogen losses through leaching. On the other hand, there is still lack of data, determined directly *in situ*, on the incorporation of nitrogen into soil organic matter, on its release, on the gaseous losses of nitrogen, particularly through biological or chemical denitrification, and on the biological fixation of N_2. No methods that would be commonly applicable in grassland research *in situ* have until now been developed for the measurement of these components of nitrogen calculation in the grassland ecosystem. These N circulation components are therefore quantified indirectly through calculations based on other directly determined data on nitrogen distribution and flow in these ecosystems. In spite of the fact that this method involves cumulative errors of different extent they provide valuable knowledge which is important for increasing the effectiveness of the N-fertilization of grasslands in long-continued fertilization programmes in comparatively stabilized meadow ecosystems.

Nitrogen circulation and distribution in a meadow ecosystem with natural grassland (*Polygalo-Nardetum strictae*), not fertilized and fertilized at rates of 100 and 200 kg of nitrogen (+PK) per ha is described by Úlehlová (1979). Annual input of nitrogen through precipitation ranged from 6 to 13 kg per ha and the input through biological fixation ranged from 1 to 5 kg per ha in the unfertilized grassland and from 1 to 0 kg per ha in plots fertilized at rates of $N_{100}PK$ and $N_{200}PK$. Increased application rates of nitrogen caused a decrease in the fixation of atmospheric nitrogen, increased the amount of nitrogen in biotic components, the nitrogen "export" through harvests, nitrogen mineralization and release from plant residues, mineral nitrogen content in the soil and also leaching of nitrogen into groundwater from 5 to 8 and 32 kg of nitrogen per ha.

In the long-term research in six most common types of meadows in the potato growing region, special attention was paid to nitrogen circulations at different nitrogen application rates. The preliminary models of circulations, elaborated on the basis of current results, were published earlier (Velich, 1978, 1981). Further, on the basis of a summary of available results of long-continued investigations on nitrogen content in the soil and in the phytomass. on harvest yields and on losses caused by leaching into underwater (Velich. 1986; Mrkvička, Velich, 1988; Velich, Mrkvička, 1989), the average amounts, and the distribution and flows of nitrogen in the meadow system are presented in this paper.

MATERIALS AND METHODS

The data refer to the 11th to 17th year of fertilization in a series of six long-term trials in the main types of permanent grassland of mesophytic nature in the potato growing region. A detailed description of the experimental meadows was given in earlier papers (Velich, Štráfelda, 1977 and others). The meadows are at an altitude of 363—634 m above sea level. The average precipitation sum for January to December is 536—662 mm (March to October 320—410 mm, average annual temperature 7—7.8 °C). The average groundwater table is 0.45—0.60 m under surface with seasonal variations of 0.2 to > 1 m. C_{ox} content in the 0—0.2 m layer ranged from 2.3 to 4.2 %, N_t content ranged from 0.23 to 0.56 %, pH (KCl) was 4.5 to 6.3, maximum sorption capacity 19 to 38 mval per 100 g, and saturation of the sorption complex with bases was 44 to 88 %. The stands were fertilized at annual rates of 0—PK—N_{100} PK—$N_{200}PK$—$N_{300}PK$—$N_{400}PK$ (index kg per ha) in the form of ammonium nitrate with limestone. These rates were divided for application to each cut, the ratio being 50 : 25 : 25. Elaborating the models of nitrogen circulation, we started from the assumption that certain fertilization rates and levels of utilization, practiced over long periods in meadow ecosystems, have led to the formation of a fluctuating equilibrium in nitrogen distribution and internal flows whose variability was mostly conditioned by the year-to-year variability of weather conditions. According to the results of investigation of the contents of C_{ox} and N_t in the soil, development of the species composition and yields in permanent meadow stands, a relative stabilization occurred six to eight years after the start of each trial. The mineralization of soil organic matter and the availability of nitrogen were determined by the method of soil isolates *in situ* (Velich, Mrkvička, 1989) and nitrogen leaching into groundwater, using field lysimeters (Velich, 1976). The inputs of symbiotically fixed N_2 nitrogen were calculated by regression equations for the relationship between weight proportion of legumes in the harvested herbage and nitrogen yields in the unfertilized and PK-fertilized plots ($r = 0.97$), from which it follows, that a 1% increase in the proportion of legumes increases nitrogen yield by 1.88 kg per ha, on an average. Data obtained under similar conditions were used for the calculation of the annual nitrogen input through precipitation (on an average 16 kg per ha). Outputs in the form of gaseous losses, mostly caused by denitrification, were calculated as the differences between nitrogen inputs and outputs in comparatively balanced meadow ecosystems.

RESULTS AND DISCUSSION

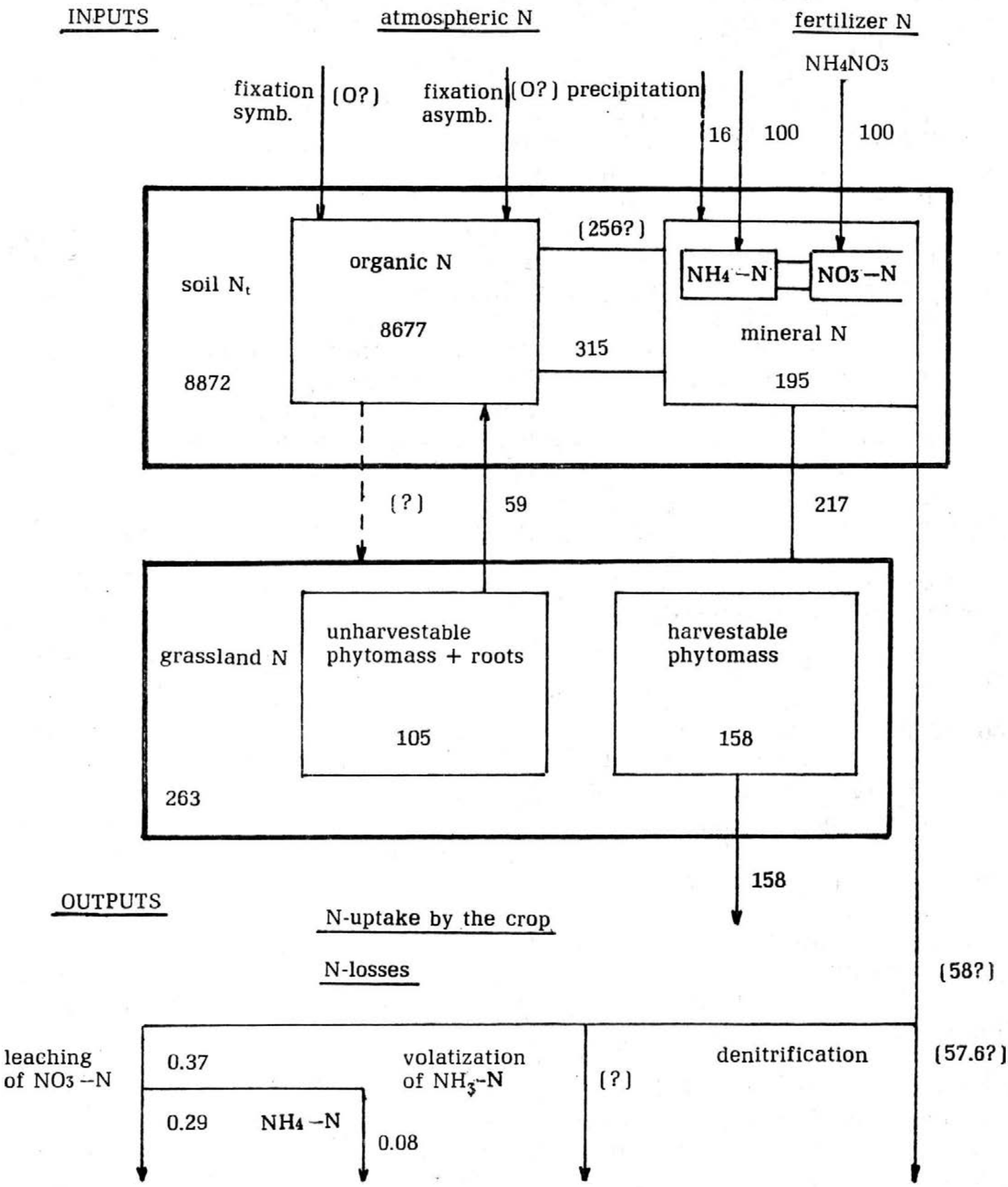
The data related to nitrogen distribution and flows in meadow ecosystems fertilized at different application rates are summed up in Tab. I. Diagrams showing, as an example, the results obtained at a fertilizer rate of N_{200}PK are given in Fig. 1. 58 kg of nitrogen was taken away with the harvested herbage from the unfertilized ecosystems at an average yield of 3.1 t dry matter per ha. The content of nitrogen in the soil was more or less constant, so that the harvest output of nitrogen as well as the nitrogen loss caused by percolation, and probably also the loss of gaseous nitrogen, were provided by nitrogen input from the atmosphere which amounted to about 25 kg of rhizobial nitrogen per ha and 16 kg of asymbiotically fixed N_2 per ha at the minimum in grasslands where the average proportion of legumes was 13.4 %. The same increase in asymbiotic N_2 fixation would then correspond to the higher losses through denitrification. A daily rate of fixation of about 2.5 mg N_2 per g (Úlehlová et al., 1984) which would correspond only to 375 g N_2 per ha fixed for the growing season or to 550 g per ha fixed for the whole year, was determined under laboratory conditions, using monoliths of a 0—40 mm layer of meadow soil containing a weight proportion of 20 to 45% water. With increasing soil moisture, the fixation increased progressively (15 times at 79 %); nevertheless. this input still could not be greater than 8 kg per ha, to say nothing of the fact that this moisture is rare in the exploited stands. At PK-fertilization 80 kg of N was removed from the grassland with an average dry matter yield of 4.1 t per ha. The proportion of legumes was 11.7 % higher, on an average (25.1 %), than in the unfertilized stands and the input of rhizobial nitrogen was about 48 kg. When the stand was fertilized at a rate of N_{100}PK, tre proportion of legumes was wery low (3 %) and the nitrogen input was about 6 kg. At higher nitrogen application rates there were almost no legumes in the stand, the dry matter yields ranging from 5.8 to 9 t per ha.

Fertilization had no clear effect on nitrogen concentration in the soil. At sites where conditions were less favourable to the mineralization

I. Nitrogen distribution and flows in grassland ecosystem (kg per ha and year) at different application rates of a long-term fertilization scheme (average for six trials in the 11th to 17th year of fertilization)

Fertilization of the grasslands		0	PK	$N_{100}PK$	$N_{200}PK$	$N_{300}PK$	$N_{400}PK$
Nitrogen inputs:	symbiotic fixation	25	48	6	0	0	0
	asymbiotic fixation*)	(17)	(16)	(0)	(0)	(0)	(0)
	nitrogen fertilizers	0	0	100	200	300	400
	precipitation	16	16	16	16	16	16
	total	58	80	122	216	316	416
Soil nitrogen:	organic nitrogen	7986	7303	7519	8677	8650	8181
	mineral nitrogen	138	149	153	195	222	230
	total	8124	7452	7672	8872	8872	8411
Nitrogen flows in the soil:	mineralization of organic nitrogen	268	345	230	315	350	328
	immobilization of mineral nitrogen	(177)	(209)	(173)	(256)	(286)	(261)
	output to phytomass	107	152	157	217	257	283
	input from unharvestable phytomass	49	72	51	59	64	67
Phytomass nitrogen:	unharvestable nitrogen + roots	93	105	92	105	112	119
	harvestable	58	80	106	158	193	216
	total	151	185	198	263	305	335
Nitrogen output:	harvestable phytomass	58	80	106	158	193	216
	leaching	0.22	0.36	0.26	0.51	0.85	2.29
	denitrification and other methods*	(0)	(0)	(15.7)	(57.5)	(122.2)	(197.7)
	total	58	80	122	216	316	416

* Data determined indirectly, or not identified



1. Nitrogen distribution and flow in the meadow ecosystems using the fertilization scheme of $N_{200}PK$ (average for six trials in the 11th to 17th year of fertilization)

□ — amount of nitrogen (kg per ha)
→ — flows of nitrogen (kg per ha and year)
(?) — data determined indirectly or not identified

of organic matter in the soil (wet localities at higher altitudes with a lower sorption capacity and lower base saturation), nitrogen fertilization led to the consolidation of a balanced content of soil nitrogen which was higher than without nitrogen fertilization; at other sites it was the same or lower. Almost regularly, this balanced state was most decreased at PK-fertilization. Fertilization increased the proportion of N_{min} out of N_t from 1.7 % in unfertilized soil to 2 % at PK-fertilization and to 2—2.2—2.5—2.7 % at N_{100}PK to N_{400}PK-fertilization.

Except the N_{100} PK treatment, fertilization increased the intensity of nitrogen conversion and flow in the soil. What is remarkable in this connection is the extraordinarily favourable effect of PK-fertilization of which exceeded in this respect even the higher PK-application rates (Tab. I). It follows from this fact that nitrogen continuosly released from the unharvestable phytomass and roots of legumes is a much more effective source for soil microflora and its decomposing activity than the readily available fertilizer nitrogen in commercial fertilizers. A depression in the mineralization of soil organic matter and nitrogen availability in N_{100}PK-fertilization which was almost regularly recorded, using different methods (minimum and maximum C_{ox} and N_t contents during a year, and decomposition tests with cellulose and protein substrate *in situ*) cannot be explained satisfactorily. Out of the total N_{org} amount in the soil, mineralization during the year at 0—PK—N_{100}PK—N_{200} PK—N_{300}PK—N_{400}PK — application rates involved 3.36—4.72—3.06——3.63—4.03—4.01 %.

Fertilization increased the proportion of ecosystem nitrogen (N_{ec}), bound at harvest in the total phytomass, from 1.8 % in the unfertilized system to 2.4—3.8 % in PK—N_{400} PK-fertilized ecosystem; this increase was mostly due to an increase in the amount of N_{ec} contained in the harvestable phytoyield. Recovery of nitrogen (= increasing of nitrogen yield as % of nitrogen supplied with fertilizers) declined with increasing nitrogen fertilization rates above 200 kg per ha. This amounted to 48——50—45—40 % at a fertilization rate of 100—200—300—400 kg of nitrogen per ha. The calculated loss of gaseous nitrogen (mostly caused by denitrification) was 16—58—122—198 kg per ha, representing 16——29—41—49 % out of the 100—200—300—400 kg of nitrogen per ha supplied with fertilizers, while the nitrogen losses caused by the leaching were wery low, not exceeding 5 kg per ha even at the highest rate of nitrogen fertilization in sand-loamy soil and in the years with higher precipitation. These losses, at nitrogen rates up to 200 kg approximately per ha correspond to the data reported by Ryden (quot. by Lazemby, 1981), according to which denitrification over the period from 15th May to 15th June causes a daily loss of 0.3 to 0.7 kg of nitrogen per ha, representing about 70 % of the total losses due to denitrification (i. e. 25—60 kg of nitrogen per ha). At nitrogen application rates of 300—400 kg per ha, the calculated losses caused by denitrification were twice to thrice higher. The much lower denitrification losses (5—8 %) in the grasslands of the temperate zone at rates of about 250 kg nitrogen per ha (Lazemby, 1981) could probably apply to the temporary grasslands of ratmher a short duration on arable land, where, except the pH value, the conditions are less favourable to denitrification (higher O_2 content, poorer root systems, lower C_{ox} content and, as a rule, lower moisture in the surface soil layer) than conditions in the sod layer of the permanent grasslands at mesophytic sites. That is why higher percolation losses of NO_3-N are recorded as a rule in the temporary grasslands than in the permanent grasslands (Havelka, Šonka, 1990 and others). Denitrification appears to be a decisive regulator of nitrogen content in meadow soils which limits nitrate leaching to groundwater at excess of ineffective nitrogen application rates.

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Na šesti trvalých loukách mezofytního charakteru v bramborářské oblasti [roční srážky 536—641 mm, teploty 7—7,8 °C; podzemní voda v průměru 0,45—0,60 m pod povrchem, ve vrstvě půdy 0—0,2 m, 2,3—4,2 % C_{ox}, C/N 5—17, pH (KCl) 4,5—6,3] byly v 11. až 17. roce hnojení 0—PK—N_{100}PK—N_{200}PK—N_{300}PK—N_{400}PK (index = kg . . ha^{-1}) zjišťovány údaje o množství, rozdělení a některých přeměnách N. Podle změn v obsahu C_{ox}, N_t, v perkolaci živin do podzemní vody, druhového složení a výnosů fytocenóz byly luční ekosystémy relativně stabilizovány. V příznivých podmínkách pro mineralizaci půdní organické hmoty se při $N_{200-400}$PK- a zejména při PK-hnojení ustálila mírně snížená hladina půdního N_t, v méně příznivých naopak. Hnojení zvyšovalo podíl N_{min} z N_t z 1,7 % u nehnojených půd na 2 až 2,7 při Při PK- až N_{400}PK-hnojení Z celkového N_{min} v půdě v pořadí hnojení 3,4—4,7—3,1—3,6—4,1——4 %. Intenzita toků N v půdě byla nejvyšší při PK-hnojení. Návratnost dávek 100—200—300—400 kg N . ha^{-1} ve zvýšených sklizních byla v průměru 48—50—45——40 %. Zcela převažující podíl na ztrátách N z ekosystému trvalých luk má denitrifikace (16—58—122—198 kg . ha^{-1}), což se též promítá v nižším vyplavování nitrátů než u dočasných travních porostů a zejména než u orné půdy.

travní porosty; trvalé louky; hnojení; koloběh dusíku

ВЕЛИХ, Й. — МРКВИЧКА, Й. — БЕЛОГОУБЕК, А. (Сельскохозяйственный институт, Прага): **Круговорот азота в луговой экосистеме при разных уровнях удобрения.** Rostl. Výr., *36*, 1990 (5) : 463-470.

На шести многолетних лугах мезофитного характера в картофельной области [годовые осадки 536—641 мм, температуры 7—7,8 °С; подземная вода в среднем 0,45—0,60 м под поверхностью, в слое почвы 0—0,2 м, 2,3—4,2 % C_{ox}, C/N 5—17, pH (KCl) 4,5—6,3] на 11—17 годы проводились удобрения 0—PK—N_{100}PK—N_{200}PK—N_{300}PK—N_{400}PK (индекс = кг/га N) для установления данных о количестве, разделении и некоторых перемен N. Согласно изменениям содержания C_{ox}, N_t, при перколяции питательных веществ в подземные воды, видового состава и выходов фитоценоз были луговые экосистемы относительно стабилизированные. При благоприятных условиях для минерализации почвеной органической массы при $N_{200-400}$PK- и главным образом при PK-удобрении установился слабо пониженный уровень почвенного N_t, при менее благоприятных наоборот. Удобрение повышало долю N_{min} с N_t из 1,7 % у неудобряемых почв на 2—2,7 % при PK- до N_{400}PK-удобрении. Из общего N_{org} в почве подвергалось минерализации в следующем порядке уровня удобрения 3,4—4,7—3,1—3,6—4,1 %. Интенсивность потока азота в почве была самой высокой при PK-удобрении. Возвращаемость доз 100—200—300—400 кг N/га в повышенных уборках составляла в среднем 48—50—45—40 %. Преобладающую долю в потерях N из экосистем постоянных лугов занимает денитрификация (16—58—122—198 кг/га), что также проявляется в более низком вымывании нитратов, чем у временных травостоев и главным образом чем у пахотной земли.

травостои; многолетние луга; удобрение; круговорот азота

VELICH, J. — MRKVIČKA, J. — BĚLOHOUBEK, A. (Landwirtschaftliche Hochschule, Praha): *Stickstoffzirkulation im Wiesenökosystem bei verschiedenen Düngungsniveaus.* Rostl. Výr., *36*, 1990 (5) : 463-470.

Auf sechs Dauerwiesen von Mesophytcharakter im Kartoffelanbaugebiet [Jahresniederschläge 536—641 mm, Temperaturen 7—7,8 °C; Grundwasser in Durchschnitt 0,45—0,60 m unter der Erdoberfläche, in der Bodenschicht 0—0,2 m, 2,3—4,2 % C_{ox}, C/N 5—17, pH (KCl) 4,5—6,3] wurden im 11. bis 17. Jahr der Düngung 0—PK—N_{100}PK—N_{200}PK—N_{300}PK—N_{400}PK (Index = kg . ha^{-1} N) Angaben über Menge, Verteilung und einige Umwandlungen des Stickstoffs ermittelt. In bezug auf Veränderungen des C_{ox}-Gehalts, den N_t, auf Perkolation der Nährstoffe in das Grundwasser, die Artenzusammensetzung und die Erträge der Phytozönosen erwiesen sich die Wiesenökosysteme als relativ stabilisiert. Bei für die Mineralisierung der organischen Bodenmasse günstigen Bedingungen bei $N_{200-400}$PK- und insbesondere dann bei PK-Düngung stabilisierte sich ein mäßig herabgesetztes Niveau des Boden-N_t, in weniger günstigen Bedingungen war es umgekehrt. Die Düngung erhöhte den Anteil N_{min} vom N_t von 1,7 % bei den ungedüngten Böden auf 2—2,7 % bei PK- bis N_{400}PK-Düngung. Vom Gesamt-N_{org} im Boden unterlagen der jährlichen Mineralisierung in der Reihenfolge der Düngungsniveaus 3,4—4,7—3,1—3,6—4,1—4 %. Die Intensität der N-Transporte im Boden war am höchsten bei der PK-Düngung. Der Rückfluß der Gaben von 100—200—300—400 kg N . ha^{-1} in Form von erhöhten Erträgen betrug im Durchschnitt 48—50—45—40 %. Einen absolut überwiegenden Anteil an den N-Verlusten aus dem Ökosystem der Dauerwiesen stellt die Denitrifikation dar (16—58—122—198 kg . ha^{-1}), was sich auch durch einen niedrigeren Grad der Nitratauswaschung als beim Wechselgrünland und insbesondere dann beim Ackerboden, bemerkbar macht.

Grünland; Dauerwiesen; Düngung; Stickstoffzirkulation

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EFFECTIVENESS OF THE RETENTION FUNCTION OF MEADOW SWARDS

F. Havelka, J. Šonka

HAVELKA, F. — ŠONKA, J. (Research Station Borkovice): *Effectiveness of the retention function of meadow swards.* Rostl. Výr., *36*, 1990 (5) : 471-480.

The effect of sown grassland, field crops, uncultivated stands and gradated nitrogen fertilization on the quality of infiltrated water studied in illimerized soil with a gleifying tendency at Klečany, Tábor district. Sown grassland was confirmed to have a stronger protective effect (38.66 mg NO_3^- at the maximum in infiltrated water) than arable land (114.4 mg NO_3^-) and uncultivated grassland (65.40 mg NO_3^-). This ability, including good yields (on an average for the years and for the application rates of 0, 80, 160, 320 kg N per ha), was recorded in the stands of timothy, red fescue, meadow fescue, smooth-stalked meadow grass and red clover (19.97 mg), in a similar stand without clover (26.02 mg), in clover-grass, timothy + red clover (38.66 mg), and in the stand of cooksfoot (38.33 mg). Combination of the application of slurry with nitrogen fertilization did not affect water quality. Nitrogen application rates up to 60 kg N per ha had no unfavourable effect on nitrate content in infilrated water in any of the grasslands under study. Nitrate content remained within the drinking water standard. At the application rate of 320 kg N per ha (combination of organic and mineral nitrogen) this standard was not exceeded in the complex stands both with and without red clover. When nitrogen was applied only in mineral form, the infiltrated waters met the requirements of the drinking water standard, except the water from under the complex grass mixtures with red clover.

grassland; composition of mixtures; gradated nitrogen fertilization; output; quality ofinfiltrated water

Intensification of agriculture through gradated application rates of mineral fertilizers, particularly nitrogen, loses its effectiveness and brings about economic and environmental problems. Particular attention is paid, in this connection, to nitrates whose content is a limiting factor in water quality. A lack of drinking water is increasingly felt; as a result, increasing importance is attached to grasslands. Grasslands have some important functions, including a very favourable and constant influence on water quality. This influence is particularly significant in comparison with that of arable crops. However, this depends, to a great extent, on a number of natural and anthropogenic factors which affect, first of all, the sod layer of the meadow soil. In this study, the effect of different species composition of grass stands is studied as exerted on the quality of infiltrated water in interaction with gradated nitrogen fertilization. The conservation function of seeded grasslands is compared with that of uncultivated grasslands and arable crops.

It was already in studies on the effectiveness and exploitation of nutrients that nutrient effectiveness was found to be associated with botanical composition. Nitrogen is exploited more intensively in stands with a worse botanical composition that grow on poor soils (Velich et al., 1970; Klesnil et al., 1980). Such stands consist of a greater number of species, including those of poorer intensity. Klesnil et al. (1978) recorded a high rate of nutrient recovery in grassland. For example, the recovery of nitrogen is 50 to 70 % in grassland, 35 to 65 % in root crops and only 22 to 55 % in cereals. This is considered to be due to the biological properties and intensity of exploitation of grassland, to the high density of rooting of the root layer of the sod and to the higher capacity of its organomineral sorption complex.

Many authors have studied the conservation function of grasslands, for example Alberda (1972), Low (1973), Hood (1976), Velich (1972), Haken, Havelka (1980), Rais (1982a), Rais, Královec (1982), Havelka, Haken (1985), Havelka (1987) and others.

Úlehlová (1985), quot. by Rychnovská et al. (1985), asserts that rain brings 13—16 kg N annually to the meadow ecosystems (Kameničky) and that the ratio between NH_4^+ and NO_3^- may differ by up to 100 %.

In the watershed of the Stříbrný potok the nitrogen contribution of rainfall is 27 to 58 kg per ha (Rais, Havelka, 1984). In the Borkovická Blata moor region, Havelka (1982) and Havelka, Rais (1982b) recorded an annual amount of 8.25 to 15.55 kg nitrogen per ha, brought to the swamp with precipitation water. The proportion of NO_3^- was 2.59 to 6.87 kg per ha, NO_2^- 0.21 to 0.66 kg per ha, and NH_4^+ 5.00 to 9.50 kg per ha.

It is highly probable that an increase in nitrate concentration in the soil solution leads to an increase in the concentrations of other ions. including those of calcium. magnesium. nitrogen, sulphates and chlorides, in the solution (Koráb, Šípek, 1989).

MATERIALS AND METHODS

The experiment with investigation of the effect of grassland composition on the quality of infiltrated water was conducted at Klečaty in the Tábor district (Research Station Borkovice, experimental area of the Research Institute for Agricultural Land Improvement, Prague. The site belongs to the Soběslav Plateau. The soil type can be characterized as illimerized soil with a gleifying tendency. Climatic characteristics: climatic district B 3, Lang's rainfall factor 80.85. Long term average precipitation (mm) and average air temperature (°C) in comparison with data for the experimental years:

Experimental year	Average for	Precipitation sum	Average temperature
long-term average	whole year	588.00	7.30
	growing season	378.00	13.50
1982	whole year	473.70	7.40
	growing season	288.30	13.59
1983	whole year	550.70	7.32
	growing season	344.80	13.85
1984	whole year	543.50	6.70
	growing season	385.70	12.50
1985	whole year	634.30	5.80
	growing season	403.70	12.81

The experiment was started in 1982. The lysimeters are located 600 mm below surface and from every four plots they emptied into a well of concrete rings. Infiltrated water is gathered in polythene containers and analyzed in the laboratory of the Borkovice Research Station.

EXPERIMENTAL TREATMENTS

Stands

Symbol	Characteristics	Sowing rate (kg per ha)
A	cooksfoot — *Dactylis glomerata*	35
B	timothy — *Phleum pratense* +	8
	+ red clover — *Trifolium pratense*	10
C	complex grass mixture without red clover	
	timothy — *Phleum pratense*	10
	red fescue — *Festuca rubra*	6
	meadow fescue — *Festuca pratensis*	10
	smooth-stalked meadow grass — *Poa pratensis*	8
D	complex grass mixture C +	
	+ red clover — *Trifolium pratense*	8
E	field crops	
	maize — *Zea mays* +	
	+ annual ryegrass — *Lolium multiflorum* var. *westerwoldicum*	
	fodder beet — *Beta vulgaris* ssp. *esculenta* var. *crassa*	
	oats — *Avena sativa* +	
	+ red clover — *Trifolium pratense* Kvarta variety	
F	Unexploited and unfertilized stand imitating uncultivated grasslands in the first water source protection zone	

Fertilization

Gradated nitrogen fertilization at rates of 0, 80, 160, 320 kg per ha. The 320-kg application rate was used either in pure inorganic form or in a combined organic (slurry) — inorganic form. PK nutrition was constant all the time: 26 kg P per ha, 75 kg K per ha. In the trial with the arable crops the zero-nitrogen treatment was not included.

Fertilizers used

N — ammonium nitrate with limestone (30 %); cattle slurry from Borkovice co-operative farm. Slurry composition was currently monitored and nitrogen was complemented to a level of 320 kg per ha, using mineral nitrogen in the form of the LAV fertilizer;
P — superphosphate;
K — potassium salt (40 %).

Data studied

Many parameters were recorded during the experiment. The following selected characteristics are given here: dry matter yield, quality of infiltrated water (contents of NO_3^-, NO_2^-, NH_4^+, PO_4^-, K^+, Ca^{++}, selected microbiological characteristics of infiltrated water at mineral N fertilization and with the use of a combination of organic and mineral nitrogen). The average values obtained in 1982 to 1985 are given in this paper.

The grass stands were harvested in three cuts (A to D). Stand F was not harvested. The experiment plots were 20 m^2 in size. Each tratment has four replications.

RESULTS AND DISCUSSION

In 1982 to 1985, the arable crops reached an average dry matter output of 3.464 t and the meadow stands (C and D) 6.360 and 6.310 t, the stand of cock's foot (A) 6.336 t and the stand of the clover-grass mixture 5.075 t per ha.

On an average for all nitrogen fertilization rates, the content of nitrates in infiltrated water was 26.02 mg NO_3^- per litre under the complex grass mixture without red clover, 19.97 mg NO_3^- per litre under the complex mixture with red clover, 38.33 mg NO_3^- under cock's foot and 38.66 mg under clover-grass mixture. Hence, it is clear that grasslands provide better water than does arable land (114.40 mg NO_3^- per litre), as stated by a number of authors (K l e s n i l et al., 1978).

Dry matter yields provide evidence of the high productivity of grasslands (Tab. I) and their positive response to increasing rates of nitrogen nutrition. The complex mixtures outyield the pure stands of cocksfoot and clover-grass at all levels of nitrogen nutrition. This corresponds with the view, held by V e l i c h et al. (1970) and K l e s n i l et al. (1978) that stands consisting of a greater number of species (often even those of a lower productivity) show a better response to nutrition in comparison with stands of intensive type. Even simple mixtures may have a high performance (K l e s n i l et al., 1978).

However, if the conservation function of grassland (reduction of contamination of infiltrated water — Tab. II) is taken into account, among other aspects, then the complex grass mixture with red clover and complex grass mixture with red clover and complex grass mixture without red clover appear to be the best, on an average. These mixtures contain bunch grasses (timothy, meadow fescue) and cultivated stoloniferous grasses (red fescue, smooth-stalked meadow grass). The nitrogen application rate of 320 kg per ha (either full mineral or combined organic and mineral nitrogen) was also evaluated from the methodical point of view. The complex mixture with red clover had NO_3^- values of 38, 33, 23 and 37 mg per litre and the mixture without clover had average nitrate levels of 72, 10 and 18.53 mg NO_3^- per litre.

Water whose average nitrate levels are as low as to comply with the standard for drinking water for babies can be found under the complex grass mixture dressed with nitrogen at a rate of up to 160 kg, under the complex grass mixture with clover dressed at a rate of up to 80 kg N, and under cock's foot with no nitrogen fertilization. The drinking water standard for adults is met by water from under the complex grass mixture with and without clover at all levels of nitrogen fertilization, by water from under the pure cock's foot stand at all fertilization levels except 320 kg N supplied only in mineral form, and by water from under the clover-grass mixture fertilizer at rates up to 160 kg N (if mineral nitrogen was combined with slurry, the total application rate could be as high as 320 kg nitrogen per ha).

Some authors K l e s n i l et al. (1978) assert that 115 kg nitrogen increases nitrate content in infiltrated water by 45 % on arable land but on temporary meadows this increase is as low as 15 %; the effect of permanent grasslands is still more pronounced. Our results indicate that the increase in nitrate content in the herbage of the complex grass

I. A survey of dry matter yields (tonnes per ha); average for 1982 to 1985

Treatment	N fertilization	Yield
A	0	3.688
	80	5.225
	160	5.733
	320	7.358
	320 (m + o)	6.366
	$\bar{x}$	6.336
B	0	4.378
	80	4.565
	160	5.281
	320	5.376
	320 (m + o)	5.873
	$\bar{x}$	5.075
C	0	4.408
	80	6.021
	160	6.408
	320	7.656
	320 (m + o)	7.303
	$\bar{x}$	6.360
D	0	5.111
	80	5.567
	160	6.233
	320	7.277
	320 (m + o)	7.304
	$\bar{x}$	6.310
E	0	—
	80	3.113
	160	3.362
	320	3.812
	320 (m + o)	3.588
	$\bar{x}$	3.464

m + o = mineral + organic nitrogen

II. Quality of infiltrated water (mg per litre)

Treatment	N (kg per ha)	NO_3^-	NO_2^-	NH_4^+	PO_4^-	K^+	Ca^{++}
A	0	9.47	0.120	0.413	0.221	1.20	25.58
	80	23.82	0.114	0.255	0.329	0.72	32.12
	160	28.74	0.299	0.485	0.603	1.16	37.23
	320	91.32	0.325	0.300	0.182	0.69	40.25
	(m + o) 320	24.94	0.068	0.247	0.202	0.81	39.25
	$\bar{x}$	38.33	0.216	0.363	0.334	0.941	33.80
B	0	24.08	0.099	0.200	0.146	1.05	33.42
	80	32.83	0.097	0.342	0.281	0.68	34.08
	160	36.38	0.083	0.228	0.124	0.79	36.52
	320	61.34	0.145	0.540	0.369	0.70	36.33
	(m + o) 320	44.23	0.091	0.244	0.170	0.79	38.54
	$\bar{x}$	38.66	0.106	0.328	0.230	0.80	35.09
C	0	8.50	0.300	0.410	0.294	0.86	30.07
	80	9.99	0.061	0.221	0.162	0.69	34.59
	160	13.50	0.039	0.155	0.153	0.96	32.20
	320	72.10	0.078	0.185	0.105	0.76	39.61
	(m + o) 320	18.53	0.113	0.382	0.210	0.94	30.66
	$\bar{x}$	26.02	0.135	0.242	0.179	0.82	34.12
D	0	11.37	0.107	0.304	0.147	0.49	31.30
	80	10.94	0.053	0.281	0.108	0.66	31.97
	160	19.25	0.066	0.360	0.300	0.85	31.97
	320	38.33	0.058	0.419	0.299	0.70	34.30
	(m + o) 320	23.37	0.065	0.330	0.218	0.83	30.86
	$\bar{x}$	19.97	0.071	0.341	0.214	0.68	32.39
E	0	—	—	—	—	—	—
	80	87.34	0.114	0.271	0.080	0.72	42.35
	160	101.17	0.079	0.214	0.045	0.80	44.89
	320	154.30	0.221	0.196	0.055	0.78	53.28
	(m + o) 320	133.01	0.093	0.217	0.050	0.94	50.52
	$\bar{x}$	114.40	0.138	0.227	0.060	0.76	46.84
F		65.40	0.179	0.629	0.295	2.45	29.41

m + o = mineral + organic nitrogen

mixture is even smaller in the case of the application rate of 160 kg nitrogen.

Our earlier results (H a v e l k a, Š o n k a, 1985) suggest that some effect is also exerted by the type of soil and that the meadow stand plays an important role in this respect. It is important, for example, whether there is a mixture for a permanent meadow, but until it is 7 years old, such a seeded permanent meadow fails to match a natural permanent meadow. This also suggests the high importance of longer development of plant species at the site and the dynamics of organic soil matter. The effect of organic matter and its quality is convincingly documented by data obtained in measurements on peaty soils (e. g. H a v e l k a, 1983, 1985). Peaty soils have a lower NO_3^- concentration in infiltrated water, regardless of the method or purpose of exploitation of the landscape. These data provide further evidence of what was published by K o e p f (1969, quoted by K l e s n i l et al., 1978).

Both in practice and theory (R a i s, K r á l o v e c, 1982), slurry appears to be a suitable material for the manuring of grasslands. Interesting data on nitrate contents were obtained when slurry was applied together with mineral nitrogen (in comparison with applying mineral nitrogen alone); this also applies to NH_4^+, except in arable crops and in the pure grass mixture. Nitrite content was lower in the combination of mineral and organic nitrogen under the stand of cock's foot and under the clover-grass mixture. It should be noted that in the case of the combination of mineral and organic nitrogen fertilization, the yields were higher in the clover-grass and in the most complex mixture. In cock's foot and in the complex grass mixture without clover, the yields obtained after the combined organo-mineral fertilization were lower than after the aplication of mineral nitrogen alone, but the preserving effect was stronger. The use of slurry increased the yields mainly in the clover component of the mixtures.

On an average for the different types of grassland, the following nitrate losses were recorded (kg NO_3^- per ha):

Grassland	kg NO_3^- per 1 ha
Cocksfoot	10.40
Timothy + red clover	17.58
Complex grass mixture without red clover	10.80
Complex grass mixture with red clover	12.65
Fodder crops on arable land	59.34
Uncultivated grassland	17.94

The total amount of percolated nitrates is also influenced by the amount of infiltrated water (litres per m^2):

Type of stand	Season		
	winter	spring	summer
Grassland	19.50	20.55	4.28
Fodder crops on arable land	37.15	20.91	8.42
Unfertilized and unexploited grassland	14.26	24.20	6.25

What deserves special mentioning is the decrease in infiltration in the grassland, in comparison with fodder crops on arable, in the winter and summer seasons.

Phosphorus is carried away in infiltrated water in larger amounts from the grasslands than from arable soil. However, clover-grass and grass mixtures have a lower phosphorus leaching than cock's foot. Phosphorus losses are high in the unexploited soil. The decrease in phosphorus is surprising.

Potassium leaching is greater in grasslands than in the arable crops at all fertilization treatments (the most complex grass mixture is the only exception). This is interesting: grasslands are generally known to accumulate potassium at high rates of potassium fertilization (e. g. K l e s n i l et al., 1978). Slurry is also known to be a nitrogen-potassium manure, and the leaching ability of potash is a well-known fact. The reason why supplementary nitrogen fertilization was used was the fact that slurry is usually applied at high rates.

The losses of calcium are lower under grass stands than under arable soil. To some extent, this supports the views concerning the need for a lower rate of the liming of meadows.

The conservation function of grasslands manifests itself also microbiologically. When 320 kg N was applied in the form of slurry and mineral N (LAV fertilizer), no *E. coli* index was recorded, nor were there any enterococci. The salmonella test was also negative. Psychrophilous and mesophilous microorganisms occurred on mass in infiltrated water. A similar picture was obtained in the treatment with fodder beet, but in the case of mesophilous microbi a level as low as 65 was recorded after mineral nutrition, whereas after application of slurry a mass occurrence was observed. A fungus was detected in the water under fodder beet dressed with slurry, though no such fungus existed in the infiltrated water under grass. This provides further evidence that grassland has a filtering function and, in this actual case, also a decontaminating function.

Even a comparatively simple mixture may have not only provide a high output and a high fodder quality (K l e s n i l et al., 1978) but also a strong conservation function. As known, temporary grassland may help to bridge leany years (T u r e k, 1970), which was confirmed in our experiments.

The most complex grass mixture was tested with success at three sites; at two of these sites it has been tested twice, and good results were obtained even on a low moor where, however, the clover component of the mixture soon disappeared. This mixture produced grasslands which have become permanent meadows with good yields and with a good conservation function (H a v e l k a, Š o n k a, 1985). The conservation function is expected to continue improving as the grass sward develops.

It is suggested by our investigation that increased supply of nitrates did not increase concentrations in infiltrated water, but this was not the case in all biogenic elements. K o r á b, Š í p e k (1989) stated this in all ions. These processes are influenced by various factors, including the dynamics of changes in the organic matter of the soil.

It appears realistic to use grassland, including the simplest mixtures, to solve the joint problems of herbage production and water resource conservation. Stands consisting of a number of species, including stoloniferous grasses and possibly also red clover, appear to be the best. The most promising results are obtained from grass stands established as permanent or cultivated original grasslands. Grassland regeneration by traditional methods reduces the conservation function of the sward, especially in the early stages. Establishment and maintenance of permanent grassland is especially important in areas round major water sources and in the vicinity of reservations. In such areas, grassland offers the only possibility of combining a high productivity, water conservation, and other favourable aspects.

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HAVELKA, F. — ŠONKA, J. (Výzkumná stance Borkovice): *Účinnost retenční funkce lučních drnů.* Rostl. Výr., *36*, 1990 (5) : 471-480.

Na illimerizované půdě se sklonem k oglejení v Klečatech v okrese Tábor byl zkoumán vliv založených travních porostů, polních plodin, neobhospodařovaného porostu a stupňované dusíkaté výživy na kvalitu infiltrovaných vod. Potvrdila se vysoká ochranná funkce travních porostů (max. 38,66 mg NO_3^- v infiltrované vodě) oproti orné půdě (114,4 mg NO_3^-) a neobhospodařovanému travnímu porostu (65,40 mg NO_3^-). Tuto schopnost včetně dobrých výnosů (v průměru sledovaných let a hnojivých dávek 0, 80, 160, 320 kg N . ha^{-1}) měly porosty bojínku lučního, kostřavy červené a luční, lipnice luční, jetele lučního (19,97 mg), podobný porost bez jetele (26,02 mg), jetelotráva, bojínek + jetel luční (38,66 mg) a porost srhy říznačky (38,33 mg NO_3^-). Kombinované hnojení kejdou s minerálním dusíkatým hnojením poskytlo dobrou kvalitu vody. Stupňované dusíkaté hnojení do 60 kg . ha^{-1} na všech sledovaných travních porostech neovlivnilo negativní obsah dusičnanů v infiltrované vodě. Obsah nitrátů byl v rámci normy pro pitnou vodu. Při dávce 320 kg N . ha^{-1} (v kombinaci anorganického a organického dusíku) nebyla tato norma překročena u porostů složitých, a to bez jetele lučního i s ním. Při aplikaci dusíku pouze v anorganické formě nebyla norma pro pitnou vodu překročena v infiltrované vodě pod porostem složitým s jetelem lučním.

travní porosty; složení směsí; stupňované dusíkaté hnojení; produkce; kvalita infiltrované vody

ГАВЕЛКА, Ф. — ШОНКА, Я. (Научно-исследовательская станция Борковице): **Эффективность функции задерживания лугового дерна.** Rostl. Výr., *36*, 1990 (5) : 471-480.

На илимеризированной почве со склоном к оглееванию в Клечатах в районе Табор исследовалось влияние травостоев, полевых культур, необрабатываемых травостоев и градации азотистого питания на качество инфильтрированных вод. Подтвердилась высокая защитная функция травостоев (макс. 38,66 мг NO_3 в инфильтрированной воде) по сравнению с пахотной землей (114,4 мг NO_3) и необрабатываемым травостойом (65,40 мг NO_3). Этими способностями хороших урожаев (в среднем исследуемых лет и доз удобрений 0, 80, 160, 320 кг . N/га) отличались травостои тимофеевки луговой, овсяницы красной и луговой, клевера лугового (19,97 мг), такой же травостой без клевера (26,02 мг), клеверотрав, тимофеевка + клевер луговой (38,66 мг) и ежи обыкновенной (38,33 мг Пз). Комбинированное удобрение навозом с минеральным азотным удобрением предоставило хорошее качество воды. Дифференцированное азотистое удобрение до 60 кг . N/га на всех исследуемых травостоях не повлияло отрицательно на содержание нитратов в инфильтрированной воде. Содержание нитратов было в рамках нормы для питьевой воды. При дозе 320 кг . N/га (в комбинации анорганического и органического азота) эта норма не была превышена у сложных травостоев, а именно без клевера лугового и с ним. При применении азота лишь в органической форме норма для питьевой воды не была превышена, лишь в инфильтрированной воде под травостеим сложным с клевером луговым.

травостои; сложные смеси; дифференцированные азотные удобрения; продукция; качество инфильтрированной воды

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QUALITY OF SURFACE WATERS IN THE PASTURE AREA

I. Rais, J. Královec, A. Kopta

RAIS, I. — KRÁLOVEC, J. — KOPTA, A. (Grassland Station Závišín, Mariánské Lázně): *Quality of surface waters in the pasture area.* Rostl. Výr., *36,* 1990 (5) : 481-488.

Quality of surface waters was studied in a watershed largely covered by a pasture area for cattle (Stříbrný potok) and in a watershed with a prevalence of arable land where water courses were iregularly lined with grassy spots (Vysočanský potok). Neither the parameters of oxygen regime, nor the essential chemical composition did change in the course of years. Surface water was evaluated as very pure. Nitrate content changed during the seven-year period but no trend can be confirmed statistically. Pasture management had no adverse effects on the quality of surface waters.

small watersheds; surface waters; quality of waters; pasture area

Cattle grazing is a technology of grassland harvest which is currently used in the potato growing, submontane and montane regions in Czechoslovakia. The animal categories that can be kept on pasture include, in practice, heifers, beef cattle and sheep. Pasture management is different for each category but mostly certain degree of specialization of large-scale production is required which in turn requires some concentration of pasture opportunities. This is important from the point of view of water resources because pasture areas are concentrated in some localities and in a number of cases they are dominant in small watersheds.

The quality of surface waters was studied in the small watershed of the Stříbrný potok where the pastures prevail and in the adjacent small stream of the Vysočanský potok with a prevalence of arable land and with intermittent grassy strips of unexploited meadow stands along the streams (Tab. I).

Grazing in protective zones of water resources is considered as risk or even undesirable. The extent to which this view is justified is the aim of this study.

MATERIALS AND METHODS

Watersheds were selected with respect to the possibility of comparing a small stream with a large proportion of cattle pasture land (Stříbrný potok) with a watershed with a larger proportion of arable land (Vysočanský potok). Both the streams are located in the western part of the Tepelská vrchovina (Tepelská Highlands) at an altitude ranging from 660 to 700 m above sea level. The climatic district B_5 has

I. Characteristics of watersheds (1981—1984)

	Arable land		Meadows and pastures		Forest		Temporarily unexploited soil		Other areas		Total	
	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%
Stříbrný potok	45.0	16.8	128.0	47.8	60.0	22.4	25.0	9.3	10.0	3.7	268.0	100
Vysočanský potok	50.4	48.4	25.5	24.5	18.5	17.8	8.2	7.9	1.4	1.4	104.0	100

an average yearly temperature of 6.4 °C (in the growing season 12.4 °C), the average yearly precipitation sum is 702 mm (for the growing season 404 mm).

It follows from the given data that the stand is characterized by a short growing season and by a comparatively high rainfall whose sum and distribution vary considerably during the growing season. As far as the terrain, climate and soil are concerned, both these watersheds are typical of the submontane regions of the Czech Socialist Republic.

The farm land of watersheds of the Stříbrný and Vysočanský potok consists of three soil associations with the following proportions:

	Association I	Association II	Association III
Stříbrný potok	70 %	20 %	10 %
Vysočanský potok	85 %	10 %	5 %

Association I practically consists only of acid brown soils, mostly deep to very deep; the soil may also be skeletal in the peaks, ridges and in exposed terrain. The soil-forming substrate is amphibolite and paragneiss. As far as the texture is concerned, the soils are light-textured to very light-textured; the soil acidic.

Association II consists of soils below water sources on slopes; they are irregularly waterlogged with the subsurface flow. Typologically, most of these soils are elluviated pseudogleys (grey brown podzolic soils, local mumic pseudogleys — as secondary soils of this association). Major part of these soils is acid, with mosaic--like waterlogging, most of them being temporarily unexploited soils (TUS).

Association III contains depression bottoms and adjacent slopes. These are most significantly waterlogged. The soil cover consists of a mosaic: catenas with increasing waterlogging. Typologically these are solely pseudogley soils, elluviated pseudogleys, humic pseudogley soils, gley soils, gley soils locally peatified, hydrogley soils. The waterlogging is of surface type, in upper part are slopes of the catena they are with more difficult outflow in the depresion.

The forest soil of the investigated watersheds is grey brown podzolic soil, medium deep on amphibolite. It is very light-textured, considerably permeable, strongly acidic, unsaturated, with low sorption capacity. Typical forest soil, suitable only for forest.

Agricultural production is concentrated on grasslands in the watershed of Stříbrný potok which are grazed down by heifers or cut for preservation (wilted silage). The species composition of the stands was as follows: cocksfoot, timothy, smooth-stalked meadow grass and white clover. The output of hay ranged from 3 to 6 t per ha. To a lesser degree, arable land on which cereals, potatoes and perennial fodder crops are rotated reaches into the watershed. Pasture technology and pasture management consist in grazing in permanently enclosed pastures. The herds are composed of 100 to 200 heads and the stocking rate is 1,000-1,200 kg of live weight per ha. The enclosed strips are equipped with watering places, feedlots and fixation devices. Animals mostly do not have to walk longer than 300 m to reach these places. Animals graze all day long, and the grazing season lasts 160 days, on an average.

The crops that prevail in the rotations used in the watershed of the Vysočanský potok include cereals, potatoes, perennial forage crops.

Nutrients, particularly nitrogen, were applied at higher rates in both the watersheds. Nitrogen was applied at two to three rates in the watershed of the Stříbrný potok and only at one to two rates in the watershed of the Vysočanský potok. The total amounts of nutrients supplied through fertilization and rainfall are given in the Tabs. VII and VIII.

The effect of pasture on surface water was determined by measuring the flow rate and chemical composition of waters. The flow rate was measured at limnigraphic stations. Besides flow rate, the amount and quality of rainfall were investigated at Závišín (at a distance of three to four km from both watersheds).

Up to 1984 the waters were sampled in both watersheds irregularly throughout the year, since 1985, with respect to the slight differences in the results of analyses, the samples were taken in the spring at the beginning of the grazing season and in the autumn after the grazing season. The samples were taken with regard to the actual start of grazing. Nitrate content was selected as the only criterion of contamination, having the largest variation. The results were evaluated by analysis of variance and the found differences were compared with the calculated differences at a minimum significance level of 5 % (D_{min} 0.05) and 1 % (D_{min} 0.01). Changes in nitrate contents were evaluated by regression analysis of several years' period.

RESULTS AND DISCUSSION

Flow rates in the Vysočanský potok and Stříbrný potok are given in Tab. II. The average outflow from 1 sq km of the watershed of the Stříbrný potok was 6.65 l per sec and in the Vysočanský potok 6.60 l per sec. This amount equals 23 % of the sum of rainfall at the Stříbrný potok

II. Average flows (1981—1984)

Watershed	1981	1982	1983	1984
	∅ flow ($l.s^{-1}$)			
Stříbrný potok	21.7	16.8	16.4	16.6
Vysočanský potok	6.8	4.1	5.7	4.9

III. Average quality of water (1981—1984)

	Stříbrný potok				Vysočanský potok			
	1981	1982	1983	1984	1981	1982	1983	1984
BOD_5	1.23	2.05	1.21	1.72	1.34	1.37	1.42	1.69
O_2 saturation	89.29	85.54	80.74	86.47	84.53	77.81	78.78	83.31
pH	7.30	7.00	6.50	7.50	7.20	6.90	6.60	7.30
SO_4^{2}	45.54	52.85	67.09	71.70	36.87	52.69	59.58	60.92
PO_4^{3-}	0.04	0.05	0.01	0.04	0.02	0.04	0.02	0.03
NO_3^-	14.40	17.30	25.20	22.40	11.90	13.80	36.30	30.10
NO_2^-	0.01	0.01	0.01	0.02	0.01	0.02	0.02	0.04
NH_4^+	0.37	0.41	0.20	0.09	0.44	0.36	0.24	0.43
K^+	0.49	1.01	1.39	1.23	0.16	0.79	1.36	0.87
Ca^{2+}	27.94	28.42	30.66	32.36	24.40	27.74	31.24	31.20

IV. Nitrate contents; Stříbrný potok — surface water (1981—1984)

Month	Year				∅	D_{min} 0.05	D_{min} 0.01
	1981	1982	1983	1984			
1.	13.4	22.4	23.7	41.5	25.2	10.4	x
2.	13.9	16.8	25.3	22.4	19.6		
3.	18.4	16.2	24.0	22.7	20.3		
4.	18.6	16.2	23.2	26.1	21.0		
5.	10.8	12.1	24.1	21.8	17.2		
6.	11.7	14.0	17.7	18.1	15.4		
7.	9.6	17.4	18.4	24.3	17.4		
8.	26.4	19.3	16.8	15.4	19.5		
9.	14.6	15.6	18.2	16.3	16.2		
10.	9.8	20.4	29.0	14.5	18.4		
11.	11.4	18.4	42.2	21.5	23.4		
12.	13.6	19.0	39.5	24.0	24.0		
∅	14.4	17.3	25.2	22.4			
D_{min} 0.05	4.6						
D_{min} 0.01	5.8						

V. Nitrate contents; Vysočanský potok — surface water (1981—1984)

Month	Year				∅	D_{min} 0.05	D_{min} 0.01
	1981	1982	1983	1984			
1.	7.0	14.2	41.0	44.4	26.6	14.4	17.1
2.	12.0	14.2	45.3	19.0	22.6		
3.	15.0	12.0	49.6	39.9	29.1		
4.	15.0	16.8	52.6	42.6	31.8		
5.	12.0	11.8	30.0	57.6	27.8		
6.	17.0	11.0	14.4	23.7	16.5		
7.	2.8	24.1	15.2	28.9	17.8		
8.	23.0	20.0	17.2	28.9	22.3		
9.	7.5	15.2	16.2	9.8	12.2		
10.	10.4	9.4	19.2	11.8	12.7		
11.	13.4	8.7	67.3	25.0	28.6		
12.	13.4	8.7	67.3	29.4	29.7		
∅	12.4	13.8	36.3	30.1			
D_{min} 0.05	6.4						
D_{min} 0.01	8.0						

VI. Nitrate contents in investigated watersheds in the spring and autumn seasons

	1981	1982	1983	1984	1985	1987	1988	D_{min} 0.05/0.01
Spring samplings								
Vysočanský potok	12.00	10.00	15.39	29.38	17.63	14.00	12.10	1.69/2.08
Stříbrný potok	9.40	13.40	15.31	16.98	17.98	15.13	11.30	
Autumn samplings								
Vysočanský potok	8.00	14.89	18.30	9.50	5.88	14.60	13.20	2.83/3.48
Stříbrný potok	11.20	22.12	17.68	15.40	13.82	15.30	11.70	

VII. Balance of nutrients in the watershed of the Stříbrný potok (1981—1984)

	1981	1982	1983	1984
Nutrients supplied through fertilization and precipitation (kg per ha)				
N	147.3	125.5	128.8	122.7
P	25.6	29.9	25.1	28.1
K	60.2	68.8	71.7	60.1
Ca	385.9	242.3	316.0	276.3
S	78.3	47.7	65.1	73.2
Outflown nutrients (kg per ha)				
N	7.571	7.593	11.051	9.919
P	0.036	0.041	0.007	0.027
K	0.850	2.075	2.823	2.589
Ca	70.469	55.519	58.976	63.504
S	39.840	32.804	44.548	46.470
Proportion of outflown nutrients out of nutrients supplied through fertilization and precipitation (%)				
N	5.14	6.05	8.58	8.08
P	0.14	0.14	0.03	0.10
K	1.41	3.02	3.94	4.31
Ca	18.26	22.91	18.66	22.98
S	50.88	68.77	68.43	63.48

VIII. Balance of nutrients in the watershed of the Vysočanský potok (1981—1984)

	1981	1982	1983	1984
Nutrients supplied through fertilization and precipitation (kg per ha)				
N	154.0	128.1	138.4	125.3
P	24.8	34.1	26.9	27.2
K	58.2	72.6	72.2	58.3
Ca	375.8	251.1	309.9	268.5
S	78.3	47.7	65.1	73.2
Outflown nutrients (kg per ha)				
N	6.076	3.953	14.574	9.877
P	0.011	0.017	0.002	0.020
K	0.200	0.912	2.710	0.990
Ca	51.566	33.190	55.315	49.010
S	26.236	22.049	37.362	29.724
Proportion of outflown nutrients out of nutrients supplied through fertilization and precipitation (%)				
N	3.95	3.09	10.53	7.88
P	0.04	0.05	0.01	0.07
K	0.34	1.26	3.75	1.70
Ca	13.72	13.22	17.85	18.25
S	33.51	46.22	57.39	40.72

and 20 % at the Vysočanský potok. This corresponds to the data reported by Zajíček (1984).

Quality of surface waters (Tab. III) is markedly influenced, beyond dispute, by rainwater in the investigated watersheds. The average composition of rainwater (in mg per l) is as follows:

Year	1981	1982	1983	1984
NO_3^-	7.02	8.47	5.93	6.14
SO_4^{2-}	19.50	15.20	22.20	27.78
Ca^{2-}	8.75	8.29	6.42	6.65

Nitrate contents in rainwater correspond to data obtained by Bulíček (1977) and Škoda (1988). The parameters of oxygen regime and basic chemical composition of surface waters in both watersheds classify the waters as very clean. Total hardness and contents of dissolved and undissolved substances are at a satisfactory level.

As to the specific parameters, attention was focused on nitrate content. The average monthly values are given in Tabs. IV and V. Nitrate contents were lower in the growing season than outside it. Svobodová (1982) arrived at a similar conclusion. The data on nitrate contents in surface water during the spring and autumn seasons for longer period of time are given in Tab. VI. Nitrate contents obviously varied as a result of climatic effects, rotating of crops and aplication of commercial and organic fertilizers. Nitrate contents exhibited no significant trend for the investigated period. Through a regression line can be drawn through the values obtained, no statistically significant regression dependence was ascertained in the limited period of time.

The amount of outflown nutrients is given in Tabs. VII and VIII. It is obvious that the amounts of outflown nitrogen, phosphorus and potassium are low, but on the other hand, the amount of outflown calcium is comparatively high.

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RAIS, I. — KRÁLOVEC, J. — KOPTA, A. (Lukařskopastvinářská stanice Závišín, Mariánské Lázně): *Kvalita povrchových vod v pastevním areálu.* Rostl. Výr., *36*, 1990 (5) : 481-488.

Kvalita povrchových vod byla sledována v povodí, kde zaujímal výrazný podíl pastevní areál pro skot (Stříbrný potok) a v povodí s převahou orné půdy, kde byly podél vodotečí zatravněné průlehy (Vysočanský potok). V průběhu let se neměnily ukazatele kyslíkového režimu ani základního chemického složení. Povrchová voda byla hodnocena jako velmi čistá. Obsah nitrátů se v průběhu sedmi let měnil, ale statisticky nelze prokázat žádnou tendenci. Pastevní hospodaření nepůsobilo negativně na kvalitu povrchových vod.

malá povodí; povrchové vody; kvalita vod; pastevní areál

РАИС, И. — КРАЛОВЕЦ, Й. — КОПТА, А. (Луго-пастбищная станция Завишин, Марианске Лазне): **Качество надземных вод в пастбищном ареале.** Rostl. Výr., *36*, 1990 (5) : 481-488.

Качество надземных вод было исследовано в бассейне, где существенную доль занимал пастбищный ареал для крупного рогатого скота (Стржибрны поток) и в бассейне с преобладанием пахотной земли, где были вдоль водотоков места с обсевом травой (Высочански поток). В течение лет не изменились показатели кислородного режима, а также основного химического состава. Надземная вода оценивалась как весьма чистая. Содержание нитратов в течение семи лет менялось, однако статистически нельзя доказать какую-либо тенденцию. Пастбищное хозяйствование не влияло отрицательно на качество надземной воды.

небольшие бассейны; надземные воды; качество воды; пастбищный ареал

RAIS, I. — KRÁLOVEC, J. — KOPTA, A. (Grünland-Station Závišín, Mariánské Lázně): *Qualität der Oberflächenwässer in einem Weideareal.* Rostl. Výr., *36*, 1990 (5) : 481-488.

Die Qualität der Oberflächenwässer wurde in einem Einzugsgebiet untersucht, wo einen beträchtlichen Anteil der Fläche ein Rinderweideareal einnahm (Stříbrný potok) und ferner in einem Einzugsgebiet mit überwiegendem Anteil an Ackerboden, wo sich entlang der Wasserläufe begraste Grabenterrassen befanden (Vysočanský potok). Im Verlauf mehrerer Jahre änderten sich weder die Parameter des Sauerstoffhaushalts noch die der grundsätzlichen chemischen Zusammensetzung. Das Oberflächenwasser wurde als sehr rein bewertet. Der Nitratgehalt variierte zwar im Verlauf von sieben Jahren, statistisch ließ sich jedoch keine Tendenz nachweisen. Die Weidewirtschaft hatte keine negative Einwirkung auf die Qualität der Oberflächenwässer.

kleine Einzugsgebiete; Oberflächenwässer; Wasserqualität; Weideareal

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CHANGES IN HERBAGE OUTPUT FROM GRASSLAND OVER TWENTY YEARS

J. Královec, A. Fryček, K. Toman, J. Baláš

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At two sites (Klatovy 420 m above sea level, Závišín 750 m a .s. l.), grasslands were studied for twenty years at gradated application rates of nitrogen (0 to 320 kg per ha) and at constant rates of phospohorus and potassium. The hay-making and multiple-cut exploitation systems were used. Over the twenty-year period, yields varied with weather, depending mainly on the levels (and distribution) of rainfall during the growing season. Larger fluctuations in yields were recorded in the control treatments (no fertilization; PK fertilizers and no nitrogen), where the proportion of clovers showed the highest variability. Division of the supply of nitrogen into three equal doses applied during the year mostly failed to provide a higher output in the given system of exploitation than did the single application of fertilizers in spring. Nitrogen fertilization was effective, in practice, only up to an application rate of 160 kg per ha. Herbage quality, evaluated from the contents of nitrogen and mineral nutrients in dry matter, remained satisfactory for the whole period of study.

grassland; long-term trials; nitrogen fertilizitation; herbage

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Grasslands as an intensification factor in the agricultural system (Kudrna, 1979) deserve closer attention, aimed mainly at maintaining their productivity. Adequate exploitation is the main prerequisite for satisfactory herbage yields; adequate (nitrogen) fertilization is another major prerequisite.

In the late nineteen-sixties, these considerations led to large-scale international research within CMEA member countries. Based on common methodology which had been worked out at the Fodder Crop Research Institute (Institut für Futterproduktion) at Paulinenauer, GDR, experiments were conducted in all European socialist countries and were finished in 1973 (Kaltofen, 1973; Fryček et al., 1974). In Czechoslovakia most of these experiments were closed in 1977 to 1980 (Baláš et al., 1981), but at two sites (Klatovy, Závišín) the trials still continue.

In the starting stage the research was focused mainly on evaluation of the rates, distribution and effectiveness of nitrogen fertilization during the growing season. Now in the final period of the research, the main objective has been to evaluate the effect of long-continued intensive nitrogen fertilization on maintaining a high grassland productivity with no adverse influence on herbage quality. This paper sums up the results obtained during the twenty years of investigation within the two experiments.

MATERIALS AND METHODS

The Klatovy trial was conducted at a site 420 m above sea level. The average annual temperature at the site is 7.6 °C (13.7 °C in the growing season) and the average annual precipitation sum is 596 mm (of this, 372 mm for the growing season). Meadow fescue, followed by white clover, prevailed in the herbage of the original association (35 and 30 % by weight, respectively). The soil at Klatovy is podzol on gneiss, sandy, slightly humic, with a slightly acid reaction (pH KCl 5.9) and an unsaturated sorption complex. When the experiment was started the soil had a low content of available phosphorus (12 mg P) and a medium content of available potassium (87 mg K per 1 kg of soil).

A reclaimed plot was chosen for the experiment at Závišín near Mariánské Lázně. It is located 750 m above sea level, on slight slope facing southeast. The site's average annual temperature is 6.4 °C (12.4 °C in the growing season) and annual rainfal total above 700 mm (of this, 400 mm for the growing season), but the year-to-year fluctuation in rainfall is great (Tab. I). The stand was established as a meadow fescue (20 % by weight) and timothy (20 %) prevailed. The Závišín soil is medium heavy-textured sandy loam with a larger content of gravel, genetic-

I. Precipitation sum for the growing season at the experimental sites

Year	Precipitation (mm)	
	Klatovy altitude 420 m a. s. l.	Závišín altitude 750 m a. s. l.
1969	296	344
1970	374	428
1971	391	369
1972	415	347
1973	299	282
1974	408	479
1975	396	409
1976	310	245
1977	477	348
1978	426	541
1979	395	396
1980	382	452
1981	476	503
1982	248	359
1983	377	469
1984	427	501
1985	408	359
1986	607	492
1987	404	414
1988	406	332

ally belonging to the acid brown soils. The parent rock is amphibolite. The soil reaction is acid (pH KCl 4.2) and the sorption complex is unsaturated. The content of available phosporus was very low (8 mg P per 1 kg of soil) and the content of available potassium was good (174 mg K per 1 kg).

The trials were based on the above-mentioned methodology of investigation in nitrogen fertilization of grassland. Phosphorus and potassium fertilization was maintained at a constant level of 32 kg P and 100 kg K per 1 ha. Nitrogen. on the other hand, was used at gradated rates (0 to 320 kg per ha), the nitrogen fertilizer being applied either in three equal doses distribution over the growing season or at a single rate, incorporated in the soil at the onset of vegetation. The nitrogen fertilizer used during the experiment was ammonium nitrate with limestone (30 % until 1981, later 27.5 % N).

The experimental plots were harvested either as meadows (twice to thrice for the growing season, the first cut being made at hay-making ripeness when the stand was 35 — 40 cm tall) or as pastures (several [usually three to four] cuts annually, first cut at a stand height of 20 cm). At both sites, on an average for the experimental years, the difference in the first cut date between the hay-making cut and multiple-cut systems of exploitation was 14 days. The dates of the first harvestes at Klatovy and Závišín were about the same, on an average for the years: the 25th to 26th of May in the multiple-cut system and 9th to 10th of June in the system with the hay-making cut.

Besides the output of dry mater, the characteristics evaluated in the experiments included the botanical composition of the herbage of the stands as the weight percentages of grasses, clovers and other herbs at all harvests of all treatments in the whole experiment. Forage quality was evaluated on the basis of inorganic plant analysis: at Závišín this has been done continuously since 1970 and at Klatovy since 1971. However, the Klatovy data for 1978, 1979, 1980 and 1986 are lacking for technical reasons. In this study, the quality of the forage is evaluated just generally by the weighted mean for nutrient contents in the herbage harvested over 19 years at Závišín and over 14 years at Klatovy. Detailed evaluation of the species composition and quality of the herbage will be the subject of a special report.

Analysis of variance was used for the elimination of random effects. To assess the uniformity of the set under study, the yields obtained from the treatments were complemented by means of the variance coefficient V, which is a percent expression of the standard deviation from the arithmetical mean.

RESULTS AND DISCUSSION

A high variability, which was particularly high between years, was recorded during the statistical evaluation. Output in the experiments (Tabs. II to V) was very dependent on weather, especially on sufficient rainfall (Tab. I) which was the only source of moisture at both sites. The coefficient of variation V for the sum of precipitation was practically the same at Závišín and Klatovy (19.6 % and 19.2 %, respectively), but that for the yields differed markedly between the two sites. The highest variability was observed in the unfertilized control treatment and in the treatment using only phosphorus and potassium fertilizers. On the other hand, the best uniformity was recorded at high rates of nitrogen fertilization, which offset the fluctuation of weather to some extent. The lower values of the variation coefficient at the system of hay-making cut, in which the first harvest represented a prevailing part of output, testifies to a greater dependence of the stands used as pastures mainly upon the distribution of rainfall during the growing season. Divided nitrogen fertilization intensified this trend.

The effect of year on output was so high that the differences in yields between the fertilization treatments within each year were often smaller than the differences between years within each treatment. In

II. Dry matter output over twenty years: multiple-cut exploitation system (Klatovy, 1969—1988)

Fertilization (kg pure nutrients per 1 ha)									
N	—	—	80*	160*	320*	80	160	240	320
P	—	32	32	32	32	32	32	32	32
K	—	100	100	100	100	100	100	100	100
Year	Dry matter yields (tonnes per 1 ha)								
1969	3.17	4.02	4.49	5.54	8.14	4.80	5.54	6.75	7.43
1970	3.42	4.30	4.43	5.40	8.24	5.07	5.98	7.03	7.66
1971	5.42	7.07	6.62	6.22	7.36	7.80	7.91	8.19	8.82
1972	4.81	5.81	7.23	6.62	7.88	7.10	7.35	8.04	8.46
1973	4.30	5.06	5.39	6.16	7.93	6.43	7.19	8.43	8.90
1974	4.32	5.68	6.10	7.43	9.68	7.21	7.50	8.76	8.74
1975	5.27	6.64	6.22	6.20	7.65	6.82	6.56	6.25	7.76
1976	2.92	3.28	3.82	3.92	4.70	4.10	4.72	4.99	5.78
1977	3.99	4.48	5.49	7.84	9.54	5.78	6.94	7.40	8.40
1978	3.92	5.67	5.08	6.41	7.37	5.80	6.92	6.94	7.78
1979	3.35	3.70	4.36	5.32	6.50	4.84	5.88	6.03	7.25
1980	4.56	6.24	5.34	7.29	8.06	6.26	7.63	8.00	9.08
1981	2.81	3.76	3.98	4.78	6.30	4.32	5.29	5.78	7.02
1982	0.92	0.99	1.50	1.96	2.31	1.62	2.20	2.59	3.07
1983	3.46	3.86	5.42	7.31	8.52	5.23	6.58	6.85	7.34
1984	1.56	1.98	2.88	4.68	6.48	3.69	4.56	5.94	6.69
1985	4.53	6.98	7.06	7.81	9.60	8.04	7.98	8.68	9.26
1986	6.59	8.50	9.48	7.78	9.50	9.10	9.44	8.36	8.74
1987	6.31	8.55	9.58	8.22	9.08	8.67	9.04	8.95	9.25
1988	4.06	5.41	6.02	6.02	7.29	6.59	7.06	7.54	7.78
Mean	3.98	5.10	5.52	6.15	7.61	5.96	6.61	7.08	7.76
Coefficient of variation									
V %	35.0	38.5	35.3	25.1	23.5	30.6	24.9	21.8	18.6

* fertilization divided into three applications.
It holds for the average yields that:
D_{min} 0.05 0.24 t per 1 ha
0.01 0.28 t per 1 ha

the majority of cases, statistically significant differences were recorded only between the extreme values. This fact can be offset, to some extent, in the average yields which also allow to identify more pronounced dependences: the average yields increased with gradated nitrogen application rates up to the highest rate used (320 kg per ha), although this tendency was not uniform. It should be noted in this

III. Dry matter output over twenty years: hay-making cut system (Klatovy, 1969—1988)

Fertilization (kg pure nutrients per 1 ha)									
N	—	—	80*	160*	320*	80	160	240	320
P	—	32	32	32	32	32	32	32	32
K	—	100	100	100	100	100	100	100	100
Year	Dry matter yields (tonnes per 1 ha)								
1969	3.16	4.08	4.24	5.10	7.13	5.14	5.93	6.62	7.45
1970	3.48	4.49	4.32	5.28	7.21	5.37	6.76	7.61	8.16
1971	4.49	5.82	5.30	5.83	6.95	6.62	7.49	8.25	8.54
1972	4.70	5.90	5.74	5.58	7.05	6.41	6.70	6.99	7.91
1973	4.02	4.56	4.76	5.24	6.72	5.43	6.71	7.26	8.10
1974	3.46	4.28	5.19	5.71	7.32	5.82	6.91	7.62	7.62
1975	4.45	4.84	4.68	4.76	5.96	5.02	5.52	6.03	7.04
1976	3.10	3.32	3.56	3.66	4.49	3.74	4.19	4.68	5.12
1977	4.22	4.32	4.90	6.33	8.42	5.44	6.50	7.38	8.73
1978	4.86	6.28	5.49	6.73	7.86	5.81	7.44	7.81	8.26
1979	4.02	4.25	5.12	6.28	7.76	4.82	5.66	5.74	6.62
1980	3.83	6.21	5.46	6.44	8.80	6.43	7.44	8.05	9.24
1981	2.92	4.38	4.43	4.66	7.08	4.42	4.90	6.08	7.20
1982	1.30	1.41	1.96	2.45	3.02	1.88	2.76	2.99	3.58
1983	2.58	3.12	4.43	5.59	6.76	4.83	6.31	6.47	7.36
1984	1.38	1.77	2.56	3.98	5.52	3.68	4.90	5.86	6.56
1985	4.11	6.26	5.72	7.11	8.91	7.22	6.96	7.99	8.74
1986	6.36	7.41	7.32	6.51	7.81	7.34	7.44	7.99	7.92
1987	4.12	6.84	6.96	6.72	7.68	6.92	7.67	7.46	7.97
1988	4.62	5.92	6.22	6.34	6.98	6.92	7.23	8.06	8.22
Mean	3.76	4.77	4.92	5.52	6.97	5.46	6.27	6.85	7.52
Coefficient of variation									
V %	31.1	33.4	26.1	21.3	20.0	25.0	20.5	19.4	17.4

* fertilization divided into three applications.
It holds for the average yields that:
D_{min} 0.05 0.23 t per 1 ha
0.01 0.27 t per 1 ha

context that the method of the experiment bears traces of the time when it was worked out (emphasis laid on maximum yields). Output was mostly higher after single application of the whole fertilizer dose in springs. Nitrogen applied in this way adds regularity to the normal course of the yield curve which has its maximum at the onset of the growing season.

It is very interesting to evaluate the production efficacy of nitrogen

IV. Dry matter output over twenty years: multiple-cut exploitation system (Závišín, 1969—1988)

Fertilization (kg pure nutrients per 1 ha)									
N	—	—	80*	160*	320*	80	160	240	320
P	—	32	32	32	32	32	32	32	32
K	—	100	100	100	100	100	100	100	100
Year	Dry matter yields (tonnes per 1 ha)								
1969	3.94	6.18	4.96	6.76	8.68	4.26	7.45	7.18	7.03
1970	2.61	4.12	5.35	6.23	7.01	4.03	6.49	6.71	7.03
1971	2.48	3.98	4.66	6.46	6.57	4.04	6.12	6.76	6.77
1972	4.08	6.11	6.42	8.70	9.12	5.68	7.98	8.31	9.09
1973	3.71	4.65	5.58	7.12	8.55	5.76	6.74	7.54	7.71
1974	4.78	6.04	6.87	9.72	9.92	7.12	9.44	9.32	8.78
1975	2.55	3.22	4.73	6.35	6.99	4.37	5.98	6.65	6.17
1976	1.91	2.54	3.92	5.21	5.55	3.86	5.18	5.55	5.07
1977	2.46	4.06	5.06	7.60	7.40	4.40	6.48	7.36	7.08
1978	2.32	3.74	5.11	6.22	7.10	4.60	6.49	6.55	6.85
1979	1.91	3.88	4.65	6.76	7.39	4.42	5.94	7.63	7.64
1980	2.33	4.32	5.05	6.72	8.24	4.45	6.69	7.62	7.91
1981	4.37	6.11	6.78	8.12	8.51	5.68	6.77	7.84	8.02
1982	2.88	5.56	5.72	8.02	8.90	5.69	6.85	7.58	8.16
1983	2.83	6.19	5.51	6.95	8.44	5.75	7.73	7.05	7.73
1984	2.67	4.58	5.59	6.11	6.99	5.09	6.61	6.56	6.43
1985	2.64	4.57	5.65	8.03	8.39	5.10	8.22	7.12	6.91
1986	2.29	4.51	4.89	7.55	9.52	4.68	6.86	7.47	7.57
1987	3.01	6.24	5.45	6.79	7.96	4.97	7.02	7.49	7.51
1988	2.72	5.66	5.40	7.47	7.71	5.36	7.04	7.09	7.69
Mean	2.95	4.81	5.37	7.14	7.95	4.97	6.90	7.27	7.36
Coefficient of variation									
V %	27.2	23.3	13.4	14.5	13.6	16.3	13.5	10.5	12.3

* fertilization divided into three applications.
It holds for the average yields that:
D_{min} 0.06 0.32 t per 1 ha
0.01 0.36 t per 1 ha

fertilization, although this is complicated by the absence of a treatment with divided application of 240 kg nitrogen per ha (this treament was not included in the experimental layout).

Velich (1968) arrived at a conclusion that from the point of view of energy, the increment of output should not fall below 15.4 kg of dry matter per the last one-kg increase in nitrogen fertilization. At

V. Dry matter output over twenty years: hay-making cut system (Závišín, 1969—1988)

Fertilization (kg pure nutrients per 1 ha)									
N	—	—	80*	160*	320*	80	160	240	320
P	—	32	32	32	32	32	32	32	32
K	—	100	100	100	100	100	100	100	100
Year	Dry matter yields (tonnes per 1 ha)								
1969	5.35	4.77	6.89	7.59	8.25	7.00	7.66	8.47	8.07
1970	6.02	4.01	6.84	7.38	7.58	6.75	7.86	7.83	8.14
1971	5.81	4.54	7.01	8.28	8.56	7.08	7.45	8.27	8.83
1972	4.70	4.21	5.30	7.16	7.43	5.51	5.59	7.71	6.98
1973	4.02	4.37	4.75	6.60	7.35	4.98	5.59	6.76	8.00
1974	4.86	4.80	6.30	8.21	9.16	7.04	6.88	8.48	8.46
1975	4.72	3.14	5.35	6.90	7.43	5.92	6.64	7.25	7.68
1976	2.80	3.09	4.90	5.50	5.68	4.70	6.00	6.19	5.96
1977	3.52	4.00	5.43	5.92	6.70	5.37	5.46	6.69	6.48
1978	3.97	4.48	5.93	6.64	7.14	5.84	6.40	7.86	6.94
1979	4.00	4.29	6.36	7.30	7.67	6.87	7.44	8.10	8.91
1980	3.81	4.86	6.32	7.28	7.73	5.38	5.67	8.98	9.05
1981	4.65	6.38	5.54	6.72	7.58	5.52	5.92	7.04	6.83
1982	4.34	6.37	5.83	7.51	8.82	5.95	6.75	7.63	8.54
1983	3.99	4.90	5.28	6.43	7.53	5.84	7.76	8.31	9.82
1984	3.56	3.67	5.12	7.00	6.59	5.46	5.69	6.74	7.28
1985	3.24	4.24	5.97	7.70	7.91	5.90	6.95	8.31	8.29
1986	3.17	5.80	5.48	7.01	7.54	5.88	6.65	8.36	8.72
1987	4.20	6.10	6.17	6.87	8.31	5.84	6.71	8.12	8.70
1988	3.04	5.89	6.40	6.99	7.42	7.16	7.09	7.29	7.63
Mean	4.19	4.70	5.86	7.05	7.62	6.00	6.61	7.72	7.97
Coefficient of variation									
V %	21.1	20.8	11.4	9.6	10.3	12.3	12.0	9.7	12.3

* fertilization divided into three applications.
It holds for the average yields that:
D_{min} 0.05 0.35 t per 1 ha
0.01 0.40 t per 1 ha

Klatovy, the production efficacy was far below this level, on an average for the experimental years, and ranged from 3.5 kg dry matter (at divided application of 80 kg N) to 9.1 kg dry matter per 1 kg of fertilizer nitrogen (at single application of 160 kg of nitrogen per ha in spring). At Závišín the production efficacy was better: on an average for the years, it was the highest at a fertilization rate (both divided and

VI. Nutrient contents in herbage: weighted mean for all harvests (Klatovy, 1971—1988)

Every-year fertilization (kg pure nutrients per 1 ha)										
N	—	—	80*	160*	320*	80	160	240	320	D_{min} 0.05/0.01
P	—	26	26	26	26	26	26	26	26	
K	—	100	100	100	100	100	100	100	100	
N, percent of dry matter										
v	2.41	2.46	2.30	2.27	2.65	2.42	2.43	2.75	3.05	0.32/0.38
l	2.12	2.15	2.07	2.02	2.30	1.95	2.09	2.31	2.67	0.31/0.36
P, percent of dry matter										
v	0.30	0.39	0.36	0.36	0.33	0.36	0.36	0.35	0.33	—
l	0.35	0.45	0.44	0.40	0.38	0.43	0.42	0.42	0.41	—
K, percent of dry matter										
v	2.34	2.88	2.91	2.72	2.44	2.94	2.75	2.68	2.59	0.18/0.21
l	2.20	2.78	2.71	2.54	2.12	2.50	2.40	2.25	2.09	0.18/0.20

* fertilization divided into three applications
—) no significance recorded
v multiple-cut exploitation system
l hay-making cut system

single) of 160 kg per 1 ha and the lowest at 320 kg per 1 ha. The lower level of production efficacy at Klatovy is largely ascribable to the comparatively high yields in the PK treatment where the proportion of clovers in the stand remained high. However, there was a considerable year-to-year fluctuation at both sites, obviously caused by the different courses of weather, particularly of sum and distribution of precipitation. This can be seen from the fact that in some years the yield declined after divided fertilization with 80 kg per 1 ha in comparison with the PK treatment, whereas after single application of the fertilizer this occurred only sporadically (more frequently at Klatovy than at Závišín; in the hay-making cut system rather than in the multiple-cut system of exploitation at both sites). Considering the output achieved and the production efficacy of nitrogen, the optimum nitrogen aplication rates were up to 160 kg per 1 ha. Application of more nitrogen was unnecessary and uneconomical.

Of course, output is influenced by the system of exploitation of the stand. The yield differences between the systems of exploitation were not very large because in the multiple-cut system the first harvest was comparatively late (the plants were 20—25 cm tall). It is perhaps better to talk about different dates of harvests of the same exploitation system rather than about different exploitation systems. As suggested by experience gathered until now, exploitation of the stand as pasture requires keeping the stand 13 cm tall for the whole growing season

VII. Nutrient contents in herbage: weighted mean for all harvests (Závišín, 1970—1988)

	Every-year fertilization (kg pure nutrients per 1 ha)									
N	—	—	80*	160*	320*	80	160	240	320	D_{min} 0.05/0.01
P	—	26	26	26	26	26	26	26	26	
K	—	100	100	100	100	100	100	100	100	
	N, percent of dry matter									
v	2.42	2.54	2.47	2.82	3.43	2.76	3.13	3.48	3.62	0.23/0.26
l	2.34	2.38	2.15	2.43	3.08	2.27	2.62	3.04	3.34	0.26/0.30
	P, percent of dry matter									
v	0.31	0.36	0.36	0.35	0.35	0.37	0.37	0.38	0.37	—
l	0.32	0.34	0.33	0.33	0.34	0.33	0.33	0.33	0.35	—
	K, percent of dry matter									
v	2.07	2.78	2.60	2.70	2.53	2.60	2.79	2.50	2.39	0.19/0.22
l	2.15	2.39	2.60	2.40	2.31	2.52	2.25	2.34	2.32	0.24/0.27

* fertilization divided into three applications
–) no significance recorded
v multiple-cut exploitation system
l hay-making cut system

(Rais, Královec, 1989); in such conditions, of course, the output as well as other parameters will be quite different. Nevertheless, it can be derived from hitherto results that divided application is justified mainly at higher levels of nitrogen nutrition and at higher frequencies of harvest, as indicated in the Rational System of Grassland Fertilization (Fryček et al., 1976; Neuberg et al., 1985).

As to the quality of the herbage, nitrogen content in herbage was observed to increase markedly with increasing nitrogen fertilization. More nitrogen in herbage was also produced when the first harvest in the multiple-cut system started earlier: the herbage of the natural grassland at Klatovy where — owing to the lower altitude above sea level — the first harvests were performed somewhat later, contained much less nitrogen than did the regenerated stand at Závišín. It should be taken into account in this respect that nitrogen content in the herbage from the first cut is often much higher than the values of weighted means given in Tabs. VI and VII. This is important with regard to the requirement for timely harvests, so nitrogen fertilization should always be divided into more than one application, particularly at high fertilization rates. What should also be borne in mind is that a high nitrogen content implies also a high content of nitrates which may affect the health of the livestock. However, it should be mentioned in this connection that, as confirmed by our results obtained from the present and other experiments (Fryček, Královec, 1979; Královec et al., 1980), grassland fertilization remains entirely safe up to a single (spring) application of 160 kg nitrogen per 1 ha which is, after all, considered as maximum bearable in normal grasslands if forage quality is to be maintained and non-productive nitrogen losses are to be avoided.

Potassium content in herbage also varied markedly with the date of harvest and with the weather in each year. However, the weighted mean for all harvests, including the unfertilized control, showed a higher potassium content than the livestock need (about 1 % K in dry matter) and higher than what is considered optimum for grassland nutrition (2.0 to 2.4 % K in dry matter). However, potassium content in herbage can hardly be controlled by fertilization alone because potassium is involved in water and nutrient transport in plants and is accumulated mainly in the dividing meristems. Hence, herbage which is younger by its development (herbage cut earlier and more frequently) contains more potassium than older material. It is suggested by the results of our parallel experiments that a long absence of potassium fertilization leads to a decline in the content of available potassium in the soil rather than to a decrease in the potassium content in herbage (Fryček et al., 1980). The use of mineral supplements to offset the increased potassium content in forage will have to continue and potassium fertilization will have to be shifted to the latter half of the growing season (Královec et al., quoted by Neuberg et al., 1985). The contents of other nutrients stayed within the optimum limits.

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Na dvou stanovištích (Klatovy, 420 m nad mořem a Závišín, 750 m nad mořem) byly po dobu dvaceti let sledované travní porosty při stupňovaném hnojení dusíkem (0 až 320 kg . ha^{-1}) a konstantní hladině fosforu a draslíku při senosečném a vícesečném využívání. Výnosy v průběhu dvaceti let kolísaly v závislosti na počasí, a to především na množství (a rozdělení) srážek za vegetaci. K větším výkyvům ve výnosech přitom docházelo na kontrolních variantách (bez hnojení a při hnojení jen fosforem a draslíkem), kde se nejvíce projevovalo proměnlivé zastoupení jetelovin. Rozdělení dodávaného dusíku do tří (shodných) dávek roku neposkytovalo většinou při daném způsobu využívání vyšší produkci píce než jednorázové jarní hnojení. Dusíkaté hnojení bylo účinné prakticky jen do 160 kg . ha^{-1}. Kvalita píce, posuzovaná podle obsahu dusíku a minerálních živin v sušině, zůstala zachována po celou dobu sledování na uspokojivé úrovni.

travní porosty; dlouhodobé pokusy; dusíkaté hnojení; kvalita píce

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На двух местопроисхождениях (Клатовы, 420 м над уровнем моря в Завишине, 750 м над у. м.) в течение двадцати лет проводилось исследование травостоев при дифференцированном удобрении азотом (0—320 кг . га) и константном уровне фосфора и калия при сенокосном и многокосном использовании. Урожаи в период двадцати лет колебались в зависимости от погоды, а именно в первую очередь от количества (и разделения) осадков в вегетационный период. Большие колебания урожаев, притом, наблюдались у контрольных вариантов (без удобрения и при удобрении лишь фосфором и калием), когда больше всего проявлялось изменчивое наличие клеверных. Разделение поставляемого азота на три (подобные) дозы в течение года, в большинстве случаев, не предоставляло при данном способе использования более высокую продукцию, чем одноразовое яровое удобрение. Азотистое удобрение было эффективным, практически, лишь до 160 кг : га. Качество зеленого корма, оцениваемое, согласно содержанию азота и минеральных питательных веществ в сухом веществе, сохранилось, за весь период исследования, на удовлетворительном уровне.

травостои; многолетние исследования; азотистые удобрения; качество зеленых кормов

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Auf zwei Standorten (Klatovy, 420 m ü.d. M. und Závišín, 750 m. ü. d. M.) verfolgten wir im Verlauf von zwanzig Jahren die Gräserbestände bei gesteigerter Stickstoffdüngung (0 bis 320 kg . ha^{-1}) und konstanten Phosphor- und Kaliumniveaus bei Ein- und Mehrschnittnutzung. Im Verlauf der zwanzig Jahre schwankten die Erträge in Abhängigkeit von der Witterung u. zw. insbesodnere von der Menge (und Verteilung) der Niederschläge während der Vegetation. Zu stärkeren Ertragsschwankungen kam es auf den Kontrollvarianten (ohne Düngung und bei Düngung ausschließlich mit Phosphor und Kalium), wo sich die variable Vertretung der Kleearten am stärksten bemerkbar machte. Die Verteilung des zugeführten Stickstoffs in drei (gleichgroße) Teilgaben im Laufe des Jahres gab bei der gegebenen Nutzungsweise meistens keine höhere Grünmasseproduktion als bei einmaliger Frühjahrsdüngung. Wirkungsvoll

war die Stickstoffdüngung praktisch nur bis zu den 160 kg . ha^{-1}. Die anhand des Stickstoff- und Mineralnährstoffgehalts in der Trockensubstanz bewertete Futterqualität blieb während der gesamten Beobachtungszeit auf befriedigendem Niveau erhalten.

Gräserbestände; Langzeitversuche; Stickstoffdüngung; Futterqualität

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PRODUCTIVITY OF GRASSLANDS IN THE BOHEMIAN-MORAVIAN UPLANDS

J. Lesák

LESÁK, J. (University of Agriculture, Brno): *Productivity of grasslands in the Bohemian-Moravian Uplands.* Rostl. Výr., *36*, 1990 (5) : 501-508.

Research was conducted by the Fodder Crop and Feed Production Department of the University of Agriculture, Brno, in the meadows and pastures of the Bohemian-Moravian Uplands in 1965 to 1985. The productivity of the grasslands included in intensity classes III and IV was found to be high, provided that there is optimum nutrition and an optimum species composition. Temporary grasslands, fertilized at a rate of 100 to 200 kg N (+ PK) per hectare, are able to produce more than 8 t dry matter per ha in four to five grazing cycles. The nutritive value of the above-ground biomass is high. Permanent meadows and stands newly established in reclaimed areas, fertilized at a rate of 150 kg N (+ PK) per ha, can produce more than 9 t of dry matter. In the region of the Bohemian-Moravian Uplands, grasslands are not only fodder producers but they also have an important landscaping function.

grassland; productivity; nutrition; succession of stands

Geomorphologically, the Bohemian-Moravian Uplands form a watershed which divides the drainage areas of the Northern Sea and the Black Sea. Acting like a meteorological barrier, it allows to retain rainfalls which are the main source of drinking and household water for the central areas of Bohemia and Moravia. Many rivers have their springs in the Uplands, e. g. the Svitava, Dyje, Sázava, Oslava, Jihlávka, Želivka, Doubravka, Chrudimka, Křetinka and others. Hence, it is very important for water management to maintain the regenerating ecosystems, i. e. forests and grasslands, in this area and to keep their function active. The structure of the areas of permanent grassland in the Bohemian-Moravian Uplands is shown in Tab. I.

For the purposes of large-scale production technologies, permanent grasslands were included in four grades of intensity. Of the total area of grasslands in the Uplands, 13.7 % was included in intensity grade I (grasslands where machines cannot be used and where the possibilities of thorough reclamation are poor). Grasslands of intensity grade II, i. e. those allowing a limited use of cultural practices and having less favourable site conditions cover 20.3 % of the total area. Good conditions for intensive cultural practices exist in 66 % of the permanent grasslands included in intensity grades III and IV (Římovský et al., 1988). The average yields of hay from the meadows in the above-mentioned areas were 3.64 t per ha in 1960 and as much as 5.66 t per ha in 1985. In the pastures the yields of hay were 1.53 t per ha in 1960 and 2.60 t in 1985.

I. Structure of permanent grasslands in the different areas of the Bohemian-Moravian Uplands

Area (district)	Grassland acreage (ha)		Decrease in acreage (%) in comparison with 1960	Grassland as % of farm land	Percent proportion	
	1960	1985			meadows	pastures
Žďár nad Sázavou	23 264	21 590	− 7.2	20.6	73.0	27.0
Jihlava	17 871	14 188	−20.6	20.1	78.6	21.4
Třebíč	12 860	9 118	−28.6	9.3	76.8	23.2
Havlíčkův Brod	18 094	16 357	− 9.6	20.3	84.9	15.1
Svitavy	16 573	13 820	−16.6	16.9	69.4	30.6
Pelhřimov	19 041	16 872	−11.4	21.0	91.0	9.0

The problems of intensification of grassland management in the Bohemian-Moravian Uplands have been studied by the Fodder Crop and Feed Production Department of the University of Agriculture, Brno, for 25 years, both on an experimental scale and on a farm scale. Some results of this investigation, particularly those concerning plant nutrition, grassland renewal and composition of grassland mixtures, are given in this paper.

MATERIALS AND METHODS

In 1968, an experiment was started in the grasslands of the Sázava Co-operative Farm to study NPK fertilization of temporary grassland. The composition of the pasture mixture is shown in Tab. II. The parameters under study included the production characteristics of the stands and the successive changes and variations in nutrient contents in the above-ground biomass. The nutrients were applied according to the following scheme:

Treatment	N	P	K
1	—	—	—
2	100	35	66
3	200	44	100
4	300	53	125

Nitrogen was applied in four parts: 45 % in spring, 30 % after the first grazing cycle, 15 % after the second grazing cycle, and 10 % after the third cycle. Phosphorus and potassium were applied in autumn.

In 1971 to 1973, research efforts were focused on the nutrition of the meadow associations and the objective was to achieve a high production efficacy and economic effectiveness of the nutrients applied. The experimental sites were chosen so as to include types of meadow stands with a species structure typical of the potato growing regions and the mountain farming area of the Bohemian-Moravian Uplands.

S á z a v a: the meadow site is located 565 m above sea level. The genetic soil representative is pseudogley sandy loam. The plot lies on a hillside. The soil profile is periodically influenced by excess moisture. This leads to the process of gleification which worsens, to some extent, the physical and chemical properties of the soil.

J á m y: the site is located at an altitude of 590 m above sea level. The relief is slightly inclined. The genetic soil representative is gley soil. The ground water table ranges between 0.3 and 0.8 m. The humus horizont h_d reaches to a depth of 230 mm. Owing to more or less permanent excess moisture, these soils are not very suitable for the cultivation of good-quality grassland.

T ř i S t u d n ě: the altitude of the site is 725 m above sea level and the terrain is slightly inclined. The pedogenetic representative is gley soil. The water table

II. Average percent proportion of species in the different pasture treatment variants (Sázava, 1968—1970)

Grazing cycle	Treatment	Clover and grass species								
		Trifolium repens	*Lotus corniculatus*	*Trifolium pratense*	*Poa pratensis*	*Festuca pratensis*	*Phleum pratense*	*Lolium perenne*	*Poa fertilis*	Other species
First to fourth	sowing	10.00	5.00	5.00	8.00	25.00	12.00	25.00	10.00	—
	1	53.00	0.31	2.11	2.32	15.08	12.95	4.36	1.71	2.16
	2	31.33	0.06	1.27	6.12	27.79	14.46	13.13	2.41	3.43
	3	17.52	0.06	0.84	14.99	33.12	14.28	10.89	2.39	5.91
	4	11.70	0.06	0.72	20.30	32.49	13.43	12.50	1.69	7.11

is 0.2 to 0.8 m under surface. The soils of this site are waterlogged all the year round and peatification occurs in some places.

Samotín: this meadow site is 755 m above sea level. Its terrain is slightly inclined. The pedogenetic representative is acid brown soil. The humus horizon reaches to a depth of 200 mm. The sandy loam (up to sandy) profile is readily permeable to rainfall.

Sněžné: the site is located 650 m above sea level and its surface is slightly inclined. The pedogentic representative is peatified gley soil. The water table usually ranges between 0.25 and 0.80 m.

As for nutrient contents, soils at all sites were high in potassium. Phosphorus content was insufficient at Tři Studně and Sněžné, good at Sázava and Samotín, and high at Jámy.

The experiment had seven variants of fertilization treatments but only three are evaluated here:

A — unfertilized control;
B — 150 kg N + 35 kg P + 62 kg K per early in spring;
C — 100 kg N + 33 kg P + 62 kg K per ha early in spring plus 50 kg N after the first cut.

Nitrogen was supplied in the form of urea, phosphorus in the form of superphosphate, and potassium in the form of 40% potassium salt.

The natural meadow stand of the *Polygalo-Nardetum* type was studied from the point of view of the complex of problems of primary production in comparison with a reclaimed and newly established meadow association. The original association as well as the newly established meadow stand were influenced by the application of the same NPK application rates at two NPK levels. The experimental plots are located in the catastral area of the village Kameničky at an altitude of 624 m above sea level.

Experimental treatments:

Block A — natural meadow association;
Block B — newly established grassland;
1 and 4 — not fertilized;
2 and 5 — 100 kg N + 22 kg P + 41.5 kg K per ha;
3 and 6 — 200 kg N + 44 kg P + 83 kg K per ha.

Two-thirds of the nitrogen application rate were applied in spring and one-third after first cut. Phosphorus and potassium were applied in spring.

RESULTS AND DISCUSSION

Temporary pastures, established in reclaimed grasslands, give high outputs of above-ground biomass in the region of the Bohemian-Moravian

III. Productivity of the temporary pasture (Sázava, 1968—1970)

Treatment	N application rate (kg per ha)	Dry matter		Crude protein	
		t per ha	rel. %	t per ha	rel. %
1	—	6.07	100.00	1.120	100.00
2	100	8.30	136.68	1.573	140.45
3	200	8.87	146.04	1.804	161.07
4	300	9.79	161.14	2.100	187.50

Uplands. Intensive fertilization still increases this output (Tab. III). The largest differences in dry matter output were recorded between unfertilized grassland and a stand fertilized with 100 kg N (+ PK) per ha. Further increase of the nitrogen application rates (200 and 300 kg per ha) does not lead to a linear increase in output, hence the efficacy of the supplied nutrients declines. Gradated nitrogen application rates had a greater influence on the output of crude protein than on the output of dry matter (Tab. III).

Gradated application rates of nutrients markedly influenced the species composition of the temporary grassland. In particular, gradated application rates of nitrogen supported the competitiveness of grasses and suppressed clovers. It was in almost all variants of treatment that the unfertilized stands and those dressed with nitrogen at rates up to 200 kg per ha had a large proportion of *Trifolium repens,* which provided a high output of above-ground biomass and influenced the quality of forage (Tab. II). As to stoloniferous grasses, *Poa pratensis* flourished best: its presence increased with the intensity of nutrition. *Festuca pratensis* and *Phleum pratense* (Tab. II) were the most vigorous loose bunch grasses. *Lotus corniculatus* and *Poa fertilis* had a poor competitiveness, so they played no significant role in intensively fertilized grasslands (L e s á k, 1971).

The productivity of various types of meadow stands manifested itself as follows at each experimental site in the Bohemian-Moravian Uplands:

IV. Effect of fertilization on production in different types of meadow stands in the Bohemian-Moravian Uplands (1971—1973)

Treatment	Fertilization	Dry matter output at the five sites									
		Sázava		Jámy		Tři Studně		Samotín		Sněžné	
		t per ha	rel. %	t per ha	rel. %	t per ha	rel. %	t per ha	rel. %	t per ha	rel. %
A	no NPK	3.98	100	6.14	100	4.90	100	2.82	100	5.33	100
B	150N + PK*	8.91	224	9.67	157	9.13	186	8.47	299	9.37	175
C	150N + PK**	7.89	198	8.73	142	9.88	202	8.00	283	9.03	169

* N — single application in spring
** N — two-thirds in spring; one-third after first cut

S á z a v a : the meadow community formed a transient association of *Festuca rubra* and *Cirsium oleraceum.* The output of dry matter in the unfertilized grassland was 3.98 t per ha; when the stand was dressed with 150 kg N (+ PK) per ha, applied early in spring, the dry matter output was 8.91 t per ha (Tab. IV).

J á m y : The site was overgrown with a cultivated seeded stand of the *Poa pratensis* and *Dactylis glomerata* type in the six harvest year. On a three-year average, the output of dry matter was 6.14 t per ha in the unfertilized stand and 9.67 t per ha in the stand dressed with 150 kg N (+ PK) per ha, applied in spring.

T ř i S t u d n ě : the meadow community of the natural grassland was included in the association of *Polygono-cirsietum palustris.* Dry matter output was 4.90 t per ha in the unfertilized stand and 9.99 t per ha in the stand fertilized with 100 kg N (+ PK) early in spring and 50 kg N per ha after the first cut (Tab. IV).

S a m o t í n : the locality had a cultivated stand in its fourth harvest year; the stand was of the *Trisetum flavescens* and *Dactylis glomerata* type. On a three-year average, dry matter output was 2.82 t per ha in the unfertilized stand and 8.47 t per ha in the grassland dressed with 150 kg N (+ PK) in spring.

S n ě ž n é : the meadow community belongs to the association of *Polygonocirsietum palustris.* Dry matter output was 5.33 t per ha in the unfertilized stand and 9.37 t per ha in the stand dressed with 150 t N (+ PK) per ha applied early in spring (Tab. IV).

It follows from these data that the meadow sites in the Bohemian--Moravian Uplands are able to produce good yields of good-quality above-ground biomass if they are adequately fertilized. The best results were obtained in those treatments when the whole intended amount of N + PK was applied early in spring. In the meadows located in the protective zones in the vicinity of water sources it is reccommended to apply two-thirds of the nitrogen in spring and the rest after the first cut (H a l v a, L e s á k, 1974).

At meadow sites located higher above the sea level, similar results at the same nitrogen application rates were obtained by V e l i c h (1986), H a k e n et al. (1981), and H a k e n (1987).

The economic effectiveness of the nutrients supplied to the grass-

V. The output of dry matter and crude protein in the natural and newly established meadow association (Kameničky, 1974—1981)

Association	Treatment	Application rate (kg N per ha)	Dry matter		Crude protein	
			t per ha	%	t per ha	%
Natural	1	–	1.71	100.00	0.180	100.00
	2	100	5.13	300.00	0.566	314.44
	3	200	7.34	429.23	0.925	513.88
Newly established	4	–	2.32	100.00	0.260	100.00
	5	100	7.95	342.67	0.824	316.92
	6	200	9.34	402.58	1.122	431.53

VI. Percent proportions of the main species in the natural meadow association (Kameničky, 1974—1981)

Year	Treatment	Plant species								
		Nardus stricta	*Deschampsia caespitosa*	*Holcus lanatus*	*Festuca rubra*	*Festuca capillata*	*Carex* ssp.	*Agrostis canina*	*Sanguisorba officinalis*	Other species
Average for 1974—1981	1	45.80	1.96	5.00	4.62	15.89	8.10	2.93	4.63	11.05
	2	12.41	20.14	19.67	9.30	7.81	0.89	4.69	2.95	12.15
	3	5.66	23.88	33.42	9.66	2.25	0.36	4.13	2.58	18.07

VII. Percent proportions of the species in the newly established meadow association (Kameničky, 1974—1981)

Year	Treatment	Plant species								
		Trifolium pratense	*Trifolium hybridum*	*Poa pratensis*	*Festuca rubra*	*Alopecurus pratensis*	*Festuca pratensis*	*Phleum pratense*	*Dactylis glomereta*	Other species
	sowing	10.00	10.00	5.00	5.00	5.00	25.00	20.00	20.00	—
Average for 1974—1981	4	5.28	7.09	3.14	17.02	6.02	16.98	10.35	6.83	27.29
	5	3.89	7.66	10.01	6.87	8.48	13.76	16.26	22.75	10.32
	6	1.75	3.83	2.26	2.26	10.48	10.40	19.38	35.54	9.50

land is shown by the relative comparison in Tab. IV: nitrogen fertilization at a rate of 150 kg per ha (+ PK), compared with the unfertilized stand, increased dry matter yield at the different sites by 57—199 %. The dry matter increment per 1 kg of nutrients (NPK) applied was 11.75 kg at the Jámy site, 18.80 kg at Samotín and 21.19 kg (treatment B) at Sázava.

From the results of scientific research efforts (1974—1981) with investigation of the primary production of herbage in a natural and newly established meadow association in relation to the anthropogenic and environmental factors it follows that gradated NPK application rates had a positive influence on the trend in the yields of above-ground biomass and nutrients. The application of 100 kg N (+ PK) per ha increased the output of above-ground biomass about three times, in comparison with the unfertilized grassland and the application of 200 kg N (+ PK) per ha increased it four times (Tab. V). Comparison of dry matter and crude protein output in natural grassland with that in a newly established meadow will show that, on an average for the years of the experiment, the newly established meadow association produced significantly larger amounts Halva, Lesák (1980).

Gradated fertilization rates had a significant influence on the succession of the meadow associations. In the natural association of the *Polygalo-Nardetum* type, nutrients supplied in fertilizers suppressed the proportion of the low-value species *Nardus stricta* and encouraged the spread of *Holcus lanatus, Deschampsia caespitosa* and *Festuca rubra* (Tab. VI). These results confirm those obtained at the same site by specialists of the Czechoslovak Academy of Sciences (Rychnovská, 1985).

The seeded clovers, *Trifolium pratense* and *Trifolium hybridum,* played an important role in the new-established meadow association in the first and second harvest year. These clover species had a positive influence on the total output and on the quality of above-ground biomass, especially in the unfertilized stand and in that dressed with 100 kg N (+ PK) per ha. The grasses that complemented successfully the clovers in these two years included, first of all, *Festuca pratensis* and *Phleum pratense; Dactylis glomerata* was also very useful in the grassland plots dressed with 200 kg N (+ PK) per ha. In the subsequent years the main producers of above-ground biomass in the fertilized stands were *Dactylis glomerata, Poa pratensis* and *Phleum pratense.* In the unfertilized stands, *Festuca rubra* and weeds spread considerably and in the eighth year of investigation they constituted as much as 70 % of above-ground biomass (Tab. VII).

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LESÁK, J. (Vysoká škola zemědělská, Brno): *Produkční schopnost lučních a pastevních porostů Českomoravské vrchoviny.* Rostl. Výr., *36*, 1990 (5) : 501-508.

Z výsledků výzkumných prací prováděných katedrou pícninářství a výroby krmiv VŠZ v Brně na loukách a pastvinách Českomoravské vrchoviny v letech 1965 až 1985 vyplývá, že produkční schopnost porostů zařazených do III. a IV. stupně intenzity při optimální výživě a vhodné botanické skladbě je vysoká. Dočasné pastevní porosty jsou schopny ve čtyřech až pěti pastevních cyklech při výživě 100 až 200 kg . . ha^{-1} N + PK poskytovat přes 8 t . ha^{-1} sušiny s vysokou nutriční hodnotou nadzemní biomasy. Trvalé i nově založené luční porosty na rekultivovaných plochách jsou schopny při výživě 150 kg . ha^{-1} N + PK poskytovat přes 9 t . ha^{-1} sušiny. Travní porosty v této oblasti mimo produkční funkce mají i velmi důležitou mimoprodukční funkci i v tvorbě a ochraně krajiny.

luční a pastevní porosty; produkční schopnost; výživa; sukcese porostů

ЛЕСАК, Й. (Сельскохозяйственный институт, Брно): **Продуктивная способность луговых и пастбищных травостоев Чешскоморавской врховины.** Rostl. Výr., *36*, 1990 (5) : : 501-508.

Результаты научно-исследовательских работ, проводимых кафедрой кормоводства и производства кормов СХИ в Брно на лугах и пастбищах Чешскоморавской врховины в 1965—1985 гг. показали, что производственная способность травостоев включенных в III и IV степени интенсивности при оптимальном питании и пригодной ботаническом составе является высокой. Временные пастбищные травостои способны за четыре—пять пастбищных цикла при питании 100—200 кг . га N + PK предоставлять свыше 8 т . га сухого вещества с высокой питательной ценностью надземной биомассы. Многолетние и новые луговые травостои на рекультивированных площадях способны при питании 150 кг . га N + PK предоставить свыше 9 т . га сухого вещества. Травостои в этой области кроме производительной функции обладают также и весьма важной внепроизведительной функцией при образовании и охране ландшафта.

луговые и пастбищные травостои; производительная способность; питание; сукцессия травостоев

LESÁK, J. (Landwirtschaftliche Hochschule, Brno): *Produktionsvermögen der Wiesen- und Weidenbestände der Böhmisch-Mährischen Höhen.* Rostl. Výr., *36*, 1990 (5) : 501-508.

Aus Ergebnissen der durch den Lehrstuhl für Futterpflanzenbau und Futterproduktion der Landwirtschaftl. Hochschule Brno in den Jahren 1965 bis 1985 vorgenommenen Forschungsarbeiten ergab sich, daß Produktionsvermögen der in die III. und IV. Intensitätsstufe eingereihten Bestände bei optimaler Ernährung und geeigneter botanischer Zusammensetzung hoch ist. Wechselweiden können in vier bis fünf Weidezyklen bei einer Ernährung von 100 bis 200 kg . ha^{-1} N + PK mehr als 8 t . ha^{-1} Trockensubstanz mit hohem Nährwert der oberirdischen Biomasse gewähren. Sowohl die Dauerwiesen als auch die neu angelegten Wiesen auf rekultivierten Flächen sind bei einer Ernährung von 150 kg . ha^{-1} N + PK imstande mehr als 9 t . ha^{-1} Trockensubstanz zu geben. Die Gräserbestände in dieser Region erfüllen neben ihrer Produktionsfunktion auch eine äußerst wichtige nichtproduktive Funktion bei der Landschaftsgestaltung und beim Landschaftsschutz.

Wiesen und Weiden; Produktionsvermögen; Ernährung; Bestandssukzession

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CHANGES IN SOME QUALITATIVE CHARACTERISTICS OF PRATOCOENOSES UNDER DIFFERENT AGROECOLOGICAL CONDITIONS AT DIFFERENTIATED NUTRITION

F. Turek, L. Kuncl

TUREK, F. — KUNCL, L. (University of Agriculture, Praha, Faculty of Agronomy České Budějovice): *Changes in some qualitative characteristics of pratocoenoses under different agroecological conditions at differentiated nutrition* Rostl. Výr., *36*, 1990 (5) : 509-518.

Productional and qualitative characteristics of permanent meadows were studied at altitudes of 550 to 900 m above sea level. The sites are characterized by the acid brown soils with various degrees of gley formation, pH value ranging from 4.0 to 5.4 with low reserve of phosphorus and good to high reserve of potassium. The species composion of the stand was varied with the dominance cockfoot, false oat, meadow fescue and meadow foxtail which significantly influenced the herbage quality. Higher nitrogen application rates increase the performance of the stands but herbage quality decreases and proportion of clovers and valuable herb species declines in the stands. A dangerous increase in nitrate contents occurs in the herbage of most phytocoenoses when 200 kg of nitrogen per ha is applied under the given conditions. Such herbage is more difficult to preserve, ß-carotene content changes, being influenced, among other factors, by the modifying effect of altitude and species composition of the stand. Potassium content increases in intensively fertilized grasslands and the ratios of potassium to sodium, calcium and magnesium widen.

grasslands; higher-altitude regions; nutrition; mineral substances; beta-carotene

High yields and optimum quality of roughage can be obtained from meadows and pastures if, first of all, there is a balanced ratio of nutrients in the soil. At present, the main concern is to provide a rational nitrogen and potassium, well-balanced with phosphorus, if high-quality herbage is to be produced. High potassium contents appear to reduce the contents of trace elements, e. g. zinc, copper, manganese and boron, available in the soil for the phytocoenose (B e d r n a, 1985).

A deficit of mineral substances including trace elements, or their inadequate ratio in the fodder, affects the health — hence also performance — of the most productive animals even though there may be plenty of protein and energy in the feed ration (V e s e l ý et al., 1984).

Other biologically active substances — vitamins also play a very important role in animal nutrition. Though they occur in the plant organisms in very low concentrations, they induce and regulate vital processes, and the metabolism of substances and energy (L a b u d a et al., 1982). Carotenes are essential for ruminants: they not only act as vitamin A (retinol) precursors, but for cattle they are also a substance with a fully independent biological activity (Davídek et al., 1983; Privalo, 1983).

Among the natural kind of fodder available in Czechoslovakia, the green fodder from the permanent graslands — pastures and meadows — contains the largest amounts of vitamins, because grassland herbage is a valuable mixture of various species and families, very often differing considerably in their nutrient contents (Thompson, 1975; Činkov, Laptev, 1976; Klesnil, Turek, 1977; Zubrický, Jenčík, 1977; Turek, Klimeš, 1984).

An important ecological factor is the altitude above sea level in the mountain and submontane regions which is negatively correlated with air temperature; thermic conditions become, under the given conditions, one of the limiting factors of plant production. The effect of altitude above sea level on the productional and qualitative parameters of perennial fodder crops on arable land was demonstrated by Habovštiak (1977), Turek, Kuncl (1987) and of protocoenoses by Turek, Klimeš (1981).

MATERIALS AND METHODS

The productional and qualitative parameters of meadows were studied at altitudes of 550 to 900 m above sea level over the years 1984—1986.

Precipitation and temperatures were monitored at two weather stations at an altitude of 600—800 m above sea level (Tab. I).

I. Precipitation and temperature

Altitude above sea level	Precipitation sum in mm for whole year/for growing season		Average temperature in °C for whole year/for growing season	
	$\bar{x}$ 1984–1986	$\bar{x}$ 50 let	$\bar{x}$ 1984–1986	$\bar{x}$ 50 let
600	678/462	715/502	4.5/10.9	6.7/12.5
800	782/507	793/543	4.8/11.2	5.5/11.5

The basic observations were performed in the exact trials at three sites of mesophytic nature 700, 800 and 900 m above sea level. The characteristics of each site are given in Tab. II.

II. Characteristics of the sites

Altitude above sea level	pH/KCl	P	K	Mg	Dominant species
		mg per kg of soil			
700	4.2	5	403	81	*Dactylis glomerata*
800	4.0	8	329	81	*Arrhenatherum elatius*
900	4.5	24	144	44	*Alopecurus pratensis*

Soil type: Acid brown soil [BSa] — pseudogley acid brown soil [BSa(g)].

Nutrition: N — in three treatments 0, 100, 200 kg (100 + 100) in pure nutrients per ha;
P — uniformly at a rate of 40 kg per ha;
K — at a rate of 50 kg per ha at the site located 900 m above sea level; at altitudes of 700 and 800 m above sea level no potassium was applied because there was plenty of potassium in the soil;

The two-cut management system was used. The exact trials were supplemented with analyses of the biomass of grasslands with different moisture regimes, extensively utilized, with a high proportion of herbs, and with nitrogen application rates up to 50 kg per ha at sites located 580 to 810 m above sea level. The analyses were carried out on the basis of Czechoslovak Standard ČSN 46 707 — Methods of Feed Testing.

RESULTS

Stand composition

Different levels of nitrogen nutrition contributed significantly to the changes in the proportions of agrobotanical groups and separate species in interaction with the altitude of the stand. The largest differences can be seen in the agrobotanical group of grasses whose dominance increased significantly with gradated nitrogen rates at an altitude of 700 m above sea level, whereas at an altitude 900 m above sea level the changes were comparatively small. *Dactylis glomerata* responded best to increased nitrogeneous nutrition.

Nitrogen nutrition is a factor that highly improves stand canopy. A rate of 100 kg of nitrogen per ha was sufficient (Tab. III).

III. Dominance of agrobotanical groups in % in the third year after differentiated fertilization

N rate in kg per ha	Altitude above sea level (m)					
	700		800		900	
	T/V/B	total	T/V/B	total	T/V/B	total
0	42/10/32	84	45/10/33	88	56/8/25	87
100	58/10/32	100	56/10/31	97	61/8/23	92
200	66/ 7/27	100	64/ 9/26	99	62/7/24	93

T — grasses V — vetch family B — herbs

In the agrobotanical groups of the vetch family and herbs, especially in the valuable species, the nitrogen nutrition appeared to be a factor limiting their effectiveness in the coenosis.

Herbage output

The productivity of permanent grasslands slightly decreased with an increasing altitude above sea level at which the site was located. Nitrogen nutrition significantly influenced the variability of output (Tab. IV).

IV. Dry matter output in t per ha and effectiveness of 1 kg of nitrogen in kg per kg of dry matter (average for 1984—1986)

N rate in kg per ha	Altitude above sea level (m)					
	700		800		900	
	output	N-effectiveness	output	N-effectiveness	output	N-effectiveness
0	7.55	—	7.40	—	7.20	—
100	10.60	30.5	10.20	38.0	9.50	23.0
200	10.70	15.8	10.55	15.8	10.25	15.3

The limit difference for $P_{0.05}$ is 0.41 t of dry matter per ha and for $P_{0.01}$ it is 0.56 t of dry matter per ha.

Productive efficiency of nitrogen fertilization was inversely dependent on the altitude of the sites; the highest value (30.5 kg dry matter per 1 kg nitrogen) was obtained at an altitude of 700 m above sea level at a rate of 100 kg of nitrogen per ha (Tab. IV).

Herbage quality at intensive nutrition with nitrogen

At all sites, increased nitrogen nutrition led to an increase in the contents of crude protein (CP) and digestible crude protein (DCP) in herbage (Tab. V). With the parallel modifying effect of altitude and with the altitude-dependent pedoclimatic factors and stand composition, the highest (CP) values were recorded at an altitude of 700 m (208.6 g crude protein per kg of dry matter) and the lowest values at an altitude of 900 m above sea level (on the average 170.9 g crude protein per kg dry matter).

V. Contents of important organic substances in herbage dry matter (weighted mean for all cuts for 1984—1986)

Altitude above sea level	N rate in kg per ha	Crude protein	Digestible crude protein	N-free extract	Fibre	β-carotene
		g per kg of dry matter				mg per kg of dry matter
700	0	198.9	144.5	391.1	284.3	100.6
	100	202.1	152.0	384.8	288.2	105.0
	200	224.7	170.0	356.0	287.9	90.7
800	0	171.8	124.9	412.1	305.5	67.7
	100	204.7	154.6	364.0	312.4	108.3
	200	212.8	163.0	355.8	300.8	114.6
900	0	143.7	107.0	449.9	315.4	88.0
	100	177.3	136.3	392.5	320.2	89.3
	200	191.8	144.3	369.6	312.1	115.7

VI. Contents of selected mineral substances in herbage dry matter (weighted mean for all cuts for 1984—1986)

Altitude above sea level	N rate in kg per ha	Ash	P	K	Ca	Mg	Na	NO_3^-
		g per kg of dry matter						
700	0	95.7	3.0	36.4	5.0	1.7	0.14	3.3
	100	94.9	4.5	35.4	4.9	1.6	0.17	6.5
	200	101.4	4.9	41.6	5.3	1.5	0.42	13.9
800	0	80.6	3.4	36.6	4.4	1.7	0.14	2.2
	100	85.7	3.8	38.2	4.1	1.8	0.16	5.9
	200	100.6	4.6	42.1	4.2	1.8	0.21	16.3
900	0	61.0	3.1	19.8	5.1	1.4	0.14	0.7
	100	80.0	4.4	32.6	4.7	1.4	0.18	3.4
	200	96.5	5.2	38.3	4.2	1.6	0.27	38.5

There were similar dependences in the case of nitrate content in the herbage; the difference was that at a rate of 200 kg of nitrogen per ha the absolutely highest nitrate content of 38.5 g NO_3^- per kg of dry matter was recorded at an altitude of 900 m above sea level.

The limit of health safety (3.1 g of NO_3^- per kg of dry matter, as reported by Javorský et al. (1987) was exceeded at all sites already at a rate of 100 kg of nitrogen applied per ha. The toxicity threshold (9.2 g of NO_3^- per kg of dry matter) was exceeded at a rate of 200 kg of nitrogen per ha (Tab. VI).

A direct dependence was recorded between altitude of the sites and fibre content. The values were increased, on an average, from 286.8 g per kg of dry matter at an altitude of 700 m to 315.9 g per kg of dry matter at an altitude of 900 m above sea level (Tab. V). In the treatments with no nitrogen fertilizers, a direct dependence was found between an altitude and the contents of nitrogen-free extract. Nitrogen nutrition, especially a rate of 200 kg per ha, significantly reduced these differences but at the same time it caused an absolute decrease in nitrogen-free extract, and thereby also in the available energy, including a worsening the ensiling capacity.

Ash contents decreased (97.3—89.0—79.2 g per kg of dry matter, on an average) with increasing altitudes, and the species composition of the stand played an important role in this. With higher nitrogen rates, the effect of dominant species manifested itself most favourably in the relation to the potassium content and its ratio to sodium. In this respect, the effect of *Alopecurus pratensis* can be regarded as favourable. Higher nitrogen fertilizer rates caused, besides an increase in potassium in the herbage, also an increase of phosphorus and sodium contents at all sites. The variability of calcium and magnesium contents was low (Tab. VI).

At an altitude of 700 m above sea level, the content of β-carotene (Tab. V) was the highest, on anaverage, at a nitrogen application rate of 100 kg per ha, and decreased when nitrogen was applied at a rate of 200 kg per ha. However, at higher altitudes of 800 and 900 m above sea level, nitrogen application rates increased up to 200 kg per ha, particularly in the second cut, had a positive effect on vitamin value of the herbage, especially in the second cut. The vitamin value of the herbage from the second cuts, in comparison with the first cut, was significantly higher three to five times (Tab. VII) in all the stands studied. *Arrhenatherum elatius* appears to be the best source of β-carotene of all the grass species studied.

VII. Content of β-carotene in mg per kg of herbage dry matter from the first and second cuts (average for 1984—1986)

N rate in kg per ha	Altitude above sea level (m)					
	700		800		900	
	first cut	second cut	first cut	second cut	first cut	second cut
0	55	161	29	120	23	174
100	40	185	51	178	38	163
200	27	169	34	213	38	217

Herbage quality of the grasslands with low intensity of nutrition and exploitation

Chemical analyses of the herbage based on samples taken from 10 extensively managed permanent grasslands, characterized by different species composition, confirm some adverse effects of the intensification of the production of roughage (Tab. VIII).

VIII. Chemical composition of herbage dry matter harvested from grasslands at low rates of nutrition and high proportion of herbs; first cut (average for 1985—1986)

Altitude above sea level (m)	Dominant species	Crude protein	N-free extract	Fibre	P	K	C	Mg	NO_3^-	β-carotene (mg per kg of dry matter)
		g per kg of dry matter								
580	*Agrostis tenuis*	95.0	464.9	366.3	1.9	17.4	2.4	1.1	0.56	75
580	*Festuca rubra*	78.0	530.3	307.6	1.8	16.7	4.8	1.2	0.37	54
630	*Alopecurus pratensis*	92.7	472.6	336.5	1.8	25.5	2.6	1.4	0.83	75
700	*Festuca pratensis*	95.3	486.5	305.9	2.6	25.6	7.3	1.2	1.26	107
700	*Cynosurus cristatus*	101.2	515.5	283.8	1.4	22.8	5.2	1.6	0.61	111
720	*Poa pratensis*	95.9	474.6	341.8	3.1	16.9	4.0	1.5	1.05	94
780	*Arrhenatherum elatius*	139.0	451.3	319.4	2.1	22.5	5.5	1.4	0.81	164
800	*Arrhenatherum elatius*	107.6	526.0	303.3	2.5	26.1	5.8	2.2	0.79	73
800	*Dactylis glomerata*	85.1	497.7	325.2	2.6	23.9	2.1	1.2	0.45	58
810	*Phleum pratense*	112.4	484.2	288.9	3.7	27.3	6.8	1.1	0.69	114

Stands with a prevalance of *Arrhenatherum elatius, Festuca pratensis, Phleum pratense* and *Cynosurus cristatus* may be considered as positive with respect to quality. The favourable proportions of species of importance for fodder in all agrobotanical groups led to an increase in the content of structural substances (crude protein, phosphorus, calcium, magnesium) as well as biologically active substances (β-carotene), and to a decline in fibre content. When potassium fertilization was eliminated, the potassium content in dry matter did not decrease below 16.7 g under the given conditions and did not exceed 27.3 g per kg of dry matter.

DISCUSSION

Rational nutrition with nitrogen can significantly increase the performance of the grasslands but unbalanced nitrogeneous nutrition reduces the variedness of the species composition, supports the grasses and reduces the proportion of clovers and valuable herbs (Klesnil, Turek, 1977).

The determination of optimum nitrogen application rates is clearly reflected in the evaluation of herbage quality. In the majority of stands under study, higher nitrogen application rates increased the contents of crude protein and digestible crude protein in the herbage. However, nitrate contents in the herbage rose at the same time and β-carotene content declined at the altitude of 700 m above sea level. As suggested by the results, at higher altitudes the accumulation of nitrates in the herbage above the safe level may occur at a nitrogen application rate as low as 100 kg per ha. Some other factors also contribute to the formulation of nitrates, including first of all lower temperatures, high precipitation, and often also a short interval between the fertilization and harvest. At altitudes up to 300 m above sea level, at rates high above 100 kg of nitrogen per ha, there is no acute risk of an increase in nitrate contents above safe level (Lichner et al., 1975). *Festuca pratensis* and *Dactylis glomerata* are especially predisposed to nitrate accumulation, as also confirmed the results of other trials conducted under comparable conditions (Turek, Kuncl, 1987). Nitrate contents above the limit of toxicity, i. e. above 9.2 g of NO_3^- per kg of dry matter, was recorded when nitrogen was applied at a rate of 200 kg per ha.

The content of β-carotene decreased at application rates of 200 kg of nitrogen per ha in permanent grasslands at an altitude of 700 m above sea level whereas at higher altitudes its content increased at rates above 100 kg of nitrogen per ha, as also reported by Tušanová (1972).

In comparison with earlier trials performed under similar conditions (Turek et al.. 1986), the potassium content in herbage increased in all intensively utilized coenoses, which brought about an extension of the ratio between potassium and sodium to 170 — 236 : 1 (cf. the maximum of 150 : 1 for the period of 1978 to 1982); at an increase of the K : Na ratio above 60 : 1, metabolic disorders can be expected (Zubrický, Jenčík, 1977). The K : (Ca + Mg) ratio, the so called tetanic factor, is important from the viewpoint of feeding value; its required value is 1.8 : 1 at all cuts. This ratio extended with higher nitrogen rates in permanent grasslands, and at an application rate of 200 kg of nitrogen per ha it ranged between 6.07 to 7.11. The question of differentiated fertilization and better utilization of clovers arises in this connection. The contents of mineral substances in the forage harvested from the permanent grasslands are also considerably influenced by herbs (Klesnil, Turek, 1977).

For production of herbage high in the content of β-carotene are suitable the stands of a varied species composition with a favourable proportion of species of fodder-production importance.

False oat played a favourable role in this context. Grasses can be listed as follows in a descending order according to β-carotene content in herbage (after Thompson, 1975): *Lolium perenne* > *Poa pratensis* > *Arrhenatherum elatius* > *Festuca pratensis* > *Dactylis glomerata* > > *Phleum pratense.*

The vitamin content in the herbage of the second cuts was three to five times higher than in the first cuts. Higher levels of carotene in the herbage from the second and third cuts are also reported by Zubrický (1965).

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TUREK, F. — KUNCL, L. (Vysoká škola zemědělská, Praha, agronomická fakulta České Budějovice): *Změny některých kvalitativních ukazovatelů pratocenóz v odlišných agroekologických podmínkách při diferencované výživě.* Rostl. Výr., *36*, 1990 (5) : 509-518.

V nadmořských výškách 550 až 900 m byly sledovány produkční a kvalitativní hodnoty trvalých lučních porostů. Stanoviště charakterizující hnědé půdy kyselé s různým stupněm oglejení, pH 4,0 až 5,4, malá zásoba fosforu a dobrá až vysoká draslíku. Porostová skladba byla pestrá s dominancí srhy říznačky, ovsíku vyvýšeného, kostřavy luční a psárky luční, které významně ovlivnily jakost píce. Vyššími dávkami dusíku se zvyšuje výkonnost porostů, ale klesá jakost píce a snižuje se podíl jetelovin a hodnotných bylin v porostech. Při dávkách dusíku 200 kg . ha^{-1} dochází v daných podmínkách k nebezpečnému zvýšení obsahu dusičnanů v píci u většiny fytocenóz. Zhoršuje se konzervační schopnost píce. Mění se obsah β-karotenu, přičemž modifikační účinek nadmořské výšky a porostového složení není zanedbatelný. V intenzívně hnojených travních porostech se zvyšuje obsah draslíku a rozšiřuje jeho poměr k sodíku, vápníku a hořčíku.

travní porosty; vyšší polohy; výživa; minerální látky; beta-karoten

ТУРЕК, Ф. — КУНЦЛ, Л. (Сельскохозяйственный институт, Прага, агрономический факультет Чешске Будейовице): **Изменение некоторых качественных показателей пратоценоз в отличающихся агроэкологических условиях при дифференцированном питании.** Rostl. Výr., *36*, 1990 (5) : 509-518.

В местах с высотой над у. м. 550—900 м исследовали продуктивные и качественные величины многолетних луговых травостоев. Местонахождение характеризируют бурые кислые почвы с разной степенью оглеения, pH 4,0—5,4, небольшой запас фосфора и хороший и даже высокий запас калия. Состав травостоя был пестрый и преобладали ежа сборная, райграс французский, овсяница луговая, лисохвост луговой, которые в большой степени повлияли на качество зеленого корма. Повышенными дозами азота повышается производительность травостоя, но понижается качество зеленого корма и понижается доля клеверных и ценных трав в травостоях. При дозах азота 200 кг . га, в данных условиях наступает опасное повышение содержания нитрата в зеленом корме у большинства фитоценоз. Ухудшается способность консервирования зеленого корма. Меняется содержание β-каротина, причем действием модификации высоты над у. м. и составом травостоев нельзя пренебречь. В интенсивно удобряемых травостоях повышается содержание калия и расширяется его отношение к натрию, известняку и магнию.

травостои; высокие местонахождения; питание; минеральные вещества; бета-каротин

TUREK, F. — KUNCL, L. (Landwirtschaftliche Hochschule, Praha, agronomische Fakultät České Budějovice): *Veränderungen einiger qualitativer Merkmale von Pratozönosen in unterschiedlichen agroökologischen Bedingungen bei differenzierter Ernährung.* Rostl. Výr., *36*, 1990 (5) : 509-518.

In Meereshöhen von 550 bis 900 m. ü. d. M. untersuchte man die Produktions- und die qualitativen Werte von Dauergrünland. Der Standort ist als sauere Braunerde mit unterschiedlicher Stufe der Gleybildung zu charakterisieren, mit pH 4,0 bis 5,4, mit geringem Phospor- und gutem bis hohem Kaliumvorrat. Die Zusammensetzung des

Bestands ist mannigfaltig, mit dominierenden Knaulgras, Glatthafer, Wiesenschwingel und Wiesenfuchsschwanz, die die Futterqualität in beträchtlichem Maße beeinflußten. Durch höhere Stickstoffgaben erhöht sich die Produktivität der Bestände, die Futterqualität vermindert sich jedoch und es sinkt der Anteil von Kleearten und anderen wertvollen Futterkräutern in den Beständen. Bei Stickstoffgaben um 200 kg . ha^{-1} kommt es in den gegebenen Bedingungen zu einer Erhöhung des Nitratgehalts im Futter in den meisten Phytozönosen. Auch die Konservierfähigkeit des Futters verschlechtert sich. Es ändert sich der ß-Karotin-Gehalt, wobei die Modifikationswirkung der Seehöhe und die der Bestandszusammensetzung nicht unbedeutend sind. In intensiv gedüngten Gräserbeständen erhöht sich der Kaliumgehalt und sein Verhältnis zu Natrium, Kalzium und Magnesium erweitert sich.

Grünland; höhere Lagen; Ernährung; Mineralstoffe; Beta-Karotin

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EFFECTS OF LONG-CONTINUED NITROGEN FERTILIZATION ON NUTRIENT CONCENTRATION IN THE SOIL AND HERBAGE OF PERMANENT GRASSLAND

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FIALA, J. (Research Station Liberec): *Effects of long-continued nitrogen fertilization on nutrient concentration in the soil and herbage of permanent grassland.* Rostl. Výr., *36*, 1990 (5) : 519-528.

Trials were conducted in 1977—1987 to study the effect of changes in available nutrients, C_{ox} and pH in the soil and the effect of gradated nitrogen rates on the concentrations of nutrients and elements in the herbage dry matter of seminatural grassland. Except in the control, three- and five cut treatments were fertilized at constant rates of 31.6 kg of phosphorus per ha and 66 (83) kg of potassium per ha plus three different rates of nitrogen: 50, 150 and 300 kg per ha. A significant dependence on the time and depth of sampling was found when the parameters of soil fertility were determined. The concentrations of total nitrogen and available phosphorus were higher in all treatments under these conditions. The values of pH and C_{ox} increased only at magnesium rates up to 150 kg per ha and nitrogen rates up to 50 kg per ha, while available potassium decreased. Gradated nitrogen application rates increase the concentrations of fibre, nitrogen, phosphorus and sodium in herbage dry matter. The concentration of potassium increases only when nitrogen is applied at a rate of 50 kg per ha, and then it decreases. Nitrogen fertilization reduces the contents of calcium and magnesium.

nitrogen fertilization; available nutrients; nutrients in herbage; rynamics of nutrients

Extensive research in grassland management has suggested that yields in grass ecosystems can be increased up to the limit of potential yield capacity if plenty of moisture and macro-nutrients is supplied, particularly nitrogen. Extreme rates and unbalanced ratio of nutrients are a serious danger to the health of livestock and to the quality of animal products. Hence, it is not right to strive just for high herbage yields. what should be striven for are yields which are optimum in the sense of economic effectiveness and quality, provided in due proportions. Nitrogen is, among other factors, an evidently decisive regulator of herbage yield and quality. Its benefits for the yield and for crude protein (Tomka, 1976; Krajčovič et al., 1983; Velich, 1986; etc.) as well as its negative consequences (nitrates and increased potassium content in herbage are known well).

Potassium fertilization appears to be a problem today, especially in interaction with nitrogen. Previous preference to potassium fertilization (Wetzel, 1965) has passed into another extreme: reduction of

I. The development of concentration of available nutrients and pH in the soil at

	mg per kg	N rate	0 of N				50 N	
		date of sampling	spring		autumn		spring	
		depth in mm	0–110	100–200	0–100	100–200	0–100	100–200
Three-cut treatment	N_t	$\bar{x}$ 1977–1979	2357	1866	1890	1773	2310	1820
		$\bar{x}$ 1985–1987	2167	1733	2400	1900	2200	1967
	P	$\bar{x}$ 1977–1979	18.9	13.6	8.2	7.1	17.2	15.8
		$\bar{x}$ 1985–1987	15.0	11.3	8.7	5.7	42.0	39.3
	K	$\bar{x}$ 1977–1979	69.5	43.7	40.8	31.7	62.9	45.7
		$\bar{x}$ 1985–1987	34.7	38.3	48.0	35.7	75.7	41.7
	Mg	$\bar{x}$ 1977–1979	82.3	72.3	77.7	77.7	70.3	56.0
		$\bar{x}$ 1985–1987	128.6	102.7	126.3	99.7	109.3	83.7
	C_{ox} (%)	$\bar{x}$ 1977–1979	2.5	2.0	2.1	1.7	2.0	1.9
		$\bar{x}$ 1985–1987	2.0	1.7	2.2	1.7	2.2	1.9
	pH	$\bar{x}$ 1977–1979	4.6	4.8	4.6	4.6	4.4	1.6
		$\bar{x}$ 1985–1987	5.2	5.0	4.6	4.5	5.2	5.4
Five-cut treatment	N_t	$\bar{x}$ 1977–1979	2473	1633	1890	1505	2357	1658
		$\bar{x}$ 1985–1987	2367	2133	2467	1933	2300	1900
	P	$\bar{x}$ 1977–1979	18.0	15.3	10.5	9.1	16.3	18.4
		$\bar{x}$ 1985–1987	16.5	16.3	19.0	38.0	34.0	18.7
	K	$\bar{x}$ 1977–1979	64.9	42.0	42.8	30.0	66.5	39.7
		$\bar{x}$ 1985–1987	57.7	43.7	42.3	34.3	47.3	38.7
	Mg	$\bar{x}$ 1977–1979	76.0	65.3	76.2	108.0	80.7	62.3
		$\bar{x}$ 1985–1987	108.3	104.3	99.7	83.0	95.0	94.3
	C_{ox} (%)	$\bar{x}$ 1977–1979	2.4	1.9	1.9	1.8	2.2	1.8
		$\bar{x}$ 1985–1987	2.2	2.0	2.4	1.9	2.2	1.8
	pH	$\bar{x}$ 1977–1979	4.5	1.6	4.7	4.7	4.5	4.8
		$\bar{x}$ 1985–1987	5.3	5.0	5.4	5.3	4.8	4.9

potassium nutrition up to elimination of potassium for several years.

Unfortunately, not many authors have ever conducted long-term trials or investigated all the aspects and implications up to animal products. This is why knowledge relating to the effect of long-continued fertilization on the sward is so important.

(P, K)		150 N (P, K)				300 N (P, K)			
autumn		spring		autumn		spring		autumn	
0–100	100–200	0–100	100–200	0–100	100–200	0–100	100–200	0–100	100–200
2147	1773	2100	1890	1820	1563	2350	1657	2193	1680
2267	1967	2333	1900	2433	2067	2433	1967	2333	2000
16.6	13.3	19.5	15.1	10.1	5.6	18.1	13.7	11.9	12.9
40.0	32.7	29.0	18.3	24.7	14.3	31.0	20.7	25.7	22.0
41.2	30.5	65.9	40.3	37.7	27.5	71.9	50.0	39.7	32.0
47.0	34.0	54.3	39.7	42.7	33.3	36.3	32.0	37.3	32.7
81.0	79.7	72.0	62.3	64.2	75.0	74.7	68.3	79.7	112.5
111.3	105.3	65.3	68.0	70.0	67.3	48.7	80.3	47.3	47.3
2.4	1.7	2.5	1.9	2.2	1.5	2.5	2.0	2.2	1.8
2.3	1.9	2.1	1.8	2.5	1.9	2.1	1.8	2.3	1.8
5.1	5.2	4.5	4.8	4.5	4.6	4.5	4.7	4.6	5.0
5.1	5.1	5.0	4.9	4.5	4.6	4.4	5.0	4.3	4.5
1780	1727	1380	1960	1960	1733	2333	1657	1960	1377
2467	1933	2400	2033	2333	1967	2238	1900	2267	1900
13.3	9.5	24.5	19.0	13.7	9.7	17.2	15.6	8.9	7.6
44.0	28.7	27.7	18.0	35.7	22.0	23.3	15.0	21.3	13.0
40.0	32.5	65.2	43.0	41.0	30.8	57.9	35.3	31.0	27.8
42.0	32.3	48.0	38.3	36.7	30.7	39.3	31.0	36.3	32.0
67.0	74.7	79.0	61.7	87.2	61.7	72.7	56.7	61.7	65.7
91.7	88.7	66.0	60.7	65.0	60.0	60.7	56.0	47.0	48.3
2.1	1.7	1.7	2.0	2.1	1.6	2.3	1.9	2.1	1.9
2.2	1.7	2.3	1.9	2.3	1.7	2.0	1.7	2.1	1.7
4.7	4.9	4.6	4.8	4.7	4.8	4.4	4.6	4.5	4.6
4.6	4.8	4.7	4.9	4.7	4.8	4.6	4.8	4.4	4.6

MATERIALS AND METHODS

A 12year-trial (1976—1987) was used to study this problem in the region of the Giant Mts. at an altitude of 620 m above sea level. The site faces south exposition and has a soil-forming substrate consisting of different types of phyllites. Its soil is medium deep, slightly skeletal sandy loam of the brown soil type on colluvial mg per kg. The C/N ratio was 9.8 the degree of sorption saturation (V) = 66 %, deposits with the following starting major values: pH (KCl), P 25, K 70, Mg 105

II. Changes of concentration in the soil in comparison with initial state in %

	N_t			P			K	
	3rd cut	5th cut	$\bar{x}$	3rd cut	5th cut	$\bar{x}$	3rd cut	5th cut
0 N	104	118	111	85	170	128	84	99
50 N	104	114	109	245	239	242	110	90
150 N	118	109	114	172	155	164	99	85
300 N	110	113	112	176	147	162	71	91
$\bar{x}$	109	114	112	170	178	174	91	91

Initial state = 100 %

humic acids 15.3 %, fulvic acids 27.0 %. The twelve-year average precipitation was 910 mm per year, 470 mm for the growing season), the average daily temperature for a year is 6.3 °C, for the growing season 11.9 °C. The original stand was semi--natural dominated by *Trisetum flavescens, Festuca pratensis, Festuca rubra* and *Dactylis glomerata.*

Fertilization treatments

Three cuts

treatment 1 — unfertilized control
treatment 2 — 50 N + 32 P + 66 (83) K
treatment 3 — 150 N (3 × 50) + P, K
treatment 4 — 300 N (3 × 100) + P, K

Five cuts

treatment 5 — unfertilized control
treatment 6 — 50 N + 32 P + 66 (83) K
treatment 7 — 150 N (5 × 30) + P, K
treatment 8 — 300 N (5 × 60) + P, K

Nitrogen was applied in the form of potassium nitrate with limestone in the spring and after each cut. Phosphorus was applied as granulated superphosphate in the spring, and potassium as a 50% potassium salt in the spring; until the end of 1979, the potassium application rate was 66 kg per ha, later 83 kg per ha.

The concentration of elements and nutrients in the soil was determined every spring and autumn, using soil samples from the layers of 0—100 mm and 100—200 mm. Herbage was analysed for the contents of elements by common methods at each cut.

RESULTS

The data on available soil nutrients exhibit a high variability: 5 to 70 % between years and 20—25 % within a single growing season. The largest differences were recorded in P and Mg, smaller differences in K, N, C_{ox}, and low in pH. Marked differences in the values of the studied nutrients were observed between the dates of sampling as well as between the depths of sampling (Tab. I). The samples taken in the spring usually had higher nutrient contents than the autumn samples from both soil layers though with increasing nitrogen application rates

	Mg			Cox			pH		
$\bar{x}$	3rd cut	5th cut	$\bar{x}$	3rd cut	5th cut	$\bar{x}$	3rd cut	5th cut	$\bar{x}$
92	148	121	135	92	106	99	104	114	109
100	143	130	137	104	101	103	109	101	105
92	99	87	93	102	111	107	103	101	102
81	67	83	75	94	91	93	97	102	100
91	114	105	110	98	102	100	103	105	104

and towards the end of the investigation this trend disappeared in most vases, or was reversed. The pH values were in turn higher in the autumn at the beginning of the investigation, and in the spring at the end of it. As far as the differences between soil layers are concerned, the elements supplied through fertilization, i. e. N, P, K, always had a higher concentration in the upper soil layer of 0—100 mm. The reverse was usually the case in the values of magnesium. There is of course more oxidizable carbon in the upper layer, and the pH values are in turn, except for the unfertilized control, higher in the lower layer.

In comparison with conditions at the beginning of the investigation and with respect to the increasing nitrogen application rates, the soil reserve and pH changed as follows over the eleven years: the total nitrogen exhibits an increase, except for the spring samplings at a depth of 0—100 mm in the unfertilized plot and in the case of fertilization with 50 kg of nitrogen per ha. On the whole for all samplings, in both the three- and five-cut systems, this increase amounts to 12 % added to the initial value. There are no significant differences ascribable to the methods of application and to nitrogen application rates; an increase was also observed in the control (Tab. II). The reserve of available phosphorus increased significantly, reaching a maximum at a rate of 50 kg of nitrogen per ha; then the phosphorus reserve declined with increased nitrogen application rates. On an average, the increase in phosphorus reached 174 %. A decrease in phosphorus, compared with initial state, was recorded only in the unfertilized control with three cuts: 85 %. Available potassium always had a decreasing trend. The higher the nitrogen application rates, leading to higher fodder yields, the lower is the nitrogen reserve. Lower values were recorded also in the control; the conditions remain unchanged only at an application rate of 50 kg of nitrogen per ha. In spite of the fact that no magnesium fertilizer was applied, an increase of magnesium content (135 %) was obtained in the control and in the plot fertilized with 50 kg of nitrogen. With higher nitrogen application rates, magnesium content declined to 75 % of the initial value. Oxidizable carbon exhibited no significant changes and its content dropped to 93 % only at a nitrogen fertilizer rate of 300 kg per ha. The pH values were practically unchanged, or a slight increase was observed, proportional to decreasing nitrogen application rates, so the increase was the greatest in the control.

III. Effects of nitrogen fertilization on the concentration of dry matter and elements in dry matter (%)

	kg N per ha	1st cut	2nd cut	3rd cut	Total	1st cut	2nd cut	3rd cut	4th cut	5th cut	Total
Dry matter	0	186.3	214.4	217.5	198.6	179.9	186.1	190.7	212.4	192.0	192.7
	50	97.0	94.8	102.1	96.2	95.7	104.1	101.5	96.1	100.1	99.1
	150	98.7	96.2	107.4	100.5	97.3	97.0	96.3	98.8	99.4	97.0
	300	100.5	111.2	109.0	105.8	96.6	96.1	90.4	101.9	103.0	97.9
Fibre	0	258.7	236.6	227.4	246.8	183.4	247.2	233.1	229.8	218.1	230.3
	50	98.1	103.3	108.2	111.7	110.4	104.7	105.7	107.3	115.3	105.9
	150	103.3	103.7	117.1	105.7	107.7	106.7	103.8	107.0	108.7	106.0
	300	99.2	110.0	119.2	105.8	103.4	105.2	105.3	110.1	109.8	106.8
N	0	24.0	24.3	22.8	23.8	32.6	27.6	25.9	25.3	28.2	27.3
	50	100.5	94.0	105.7	100.1	107.9	97.2	96.5	108.1	100.2	103.3
	150	100.3	98.4	101.8	99.8	107.0	101.4	103.4	107.4	97.3	103.5
	300	105.7	90.7	109.1	102.3	123.5	120.4	115.6	115.9	107.5	116.3
P	0	4.0	4.3	2.9	4.0	5.1	4.7	5.0	5.0	5.0	4.9
	50	107.0	106.8	153.9	107.2	100.0	111.1	105.7	106.2	99.4	106.1
	150	109.5	109.1	147.1	108.9	107.1	104.1	109.1	110.6	101.0	106.8
	300	106.5	102.3	144.4	106.2	105.9	103.6	101.0	102.4	92.5	101.4
K	0	18.4	18.2	16.0	17.9	20.7	20.4	21.1	17.7	16.1	19.4
	50	121.1	113.1	102.8	117.0	122.5	113.1	112.5	112.1	105.1	115.4
	150	124.5	97.4	87.2	94.3	119.6	108.8	108.4	98.7	101.5	106.2
	300	97.9	93.0	75.2	90.8	111.6	94.1	93.6	90.8	89.4	93.0
Ca	0	5.9	8.7	8.7	7.2	5.5	7.1	7.7	8.4	8.5	7.5
	50	89.3	109.8	107.6	96.2	90.1	86.0	95.2	95.0	123.4	91.8
	150	85.6	85.2	91.8	88.4	85.5	78.5	88.3	84.7	81.7	83.3
	300	83.0	80.5	88.1	70.1	84.6	70.5	84.3	80.0	76.7	78.9
Mg	0	3.7	4.9	4.8	4.2	4.0	3.8	4.1	5.1	6.0	4.5
	50	93.5	101.6	90.9	93.6	84.6	110.2	86.7	104.3	94.6	96.4
	150	88.6	103.9	99.6	97.2	95.3	101.8	78.4	95.5	83.1	93.5
	300	94.3	91.4	93.2	94.8	90.3	97.1	94.8	94.7	93.6	97.3
Na	0	0.43	0.62	0.41	0.48	0.50	0.32	0.40	0.36	0.44	0.38
	50	111.6	80.6	119.5	102.1	124.0	137.5	112.5	130.6	127.3	128.9
	150	104.7	104.8	148.8	104.2	132.0	137.5	115.0	113.9	131.9	126.3
	300	123.3	93.5	109.8	108.3	172.0	146.9	115.0	130.6	150.0	142.1

0 lg of nitrogen per ha (g per kg) = 100 %

Gradated nitrogen application rates used in long-term fertilization systems lead to changes in dry matter concentration in green forage and nutrient concentration in dry matter, as shown in Tab. III. The average dry matter concentration was 199 g per kg at three cuts, and at five cuts it was, naturally, lower: 193 g per kg. Dry matter concentration increases successively with cuts. In the three-cut system the concentration of dry matter increases only at high nitrogen rates (300 kg nitrogen per ha). At a low nitrogen rate (50 kg per ha) the dry matter concentration decreases. In the five-cut system, the effect of fertilization on the dry matter concentration is lower: dry matter concentration declines in comparison with the control.

The average concentration of fibre was 247 g per kg in three cuts and 230 g per kg in five cuts. Fibre concentration is generally higher when nitrogen fertilizer is applied. The nitrogen concentration did not develop as expected in the three cut system and increased only by 2.3 % at the highest nitrogen application rates. In the five-cut system a greater increase (by 16.3 % in comparison with the control) occurred only when 300 kg of nitrogen was applied per ha. Phosphorus concentration was influenced more significantly by fertilizer rates of 50 to 150 kg of nitrogen per ha (phosphorus concentration higher by about 7 % than in the control), whereas high rates (300 kg of nitrogen per ha) increased it only by 1 to 6 %. Potassium concentration had an even more interesting development. Low rates of 50 kg of nitrogen per ha increased potassium concentration by 15—17 %, medium rates of 150 kg per ha increased it by 6 % in five cuts. In three cuts the medium nitrogen fertilizer rate reduces it by 6 % and a rate of 300 kg nitrogen per ha by 7 to 9 %. Nitrogen fertilizing had the worst effects on calcium concentration. This decreased progressively as much as 30 % in three cuts and 21 % in five cuts. Magnesium concentration was also adversely affected by nitrogen, by which it was reduced by 3 to 6 %. Nitrogen in turn had positive effect on sodium concentration which increases successively by 8 % or even by 42 % in five cuts.

DISCUSSION

Balanced uptake of nutrients by the plant is pointed out as a prerequisite for the formation of a high yield of grassland herbage whose nutrient proportions should be as close to the optimum as possible. For this, the nutrient contents in the soil should be adjusted to provide an optimum "nutrient offer" to the plants. It is mainly in grasslands that the importance of respecting at least the main principles of plant nutrition is often underestimated for various reasons, resulting in adverse effects (especially in the potato growing regions), caused by low contents of calcium, magnesium and sodium and by high contents of potassium and nitrates in the herbage.

It follows from the results of determination of values of available nutrients, C_{ox} and soil pH by common methods that there is a significant dependence on the date of sampling and sampling depth. For example, the amount of available phosphorus determined in the autumn reached only 38 % of value found in the spring samples. Phosphorus concentrations in samples taken from a depth of 100—200 mm averaged 76 % of those in samples from the upper layer, of 0—100 mm, etc. (Tab. I).

The standard procedures of field testing of soils for the period 1981—1990 suggest neither the data of sampling nor its depth, only Czechoslovak Standard ČSN 46 5310, valid since 1974, fixes the depth of sampling at 100 mm.

The changes in soil nutrient reserve and pH as a consequence of long-term gradated nitrogen aplication are interesting mainly in the case of potassium, magnesium, phosphorus, and pH. Potassium "export" by harvests to a level of 140—170 % of the average amount supplied with fertilizers, i. e. 75 kg of nitrogen per ha, occurred at slightly increasing yields in each variant in the three-cut system and at decreasing yields in the five-cut system. In these circumstances, in a time series of eleven years under the studied conditions, the content of available potassium decreased to 92 % of the initial level in the control (where 65 kg of potassium per ha was "exported" annually through harvests): at a nitrogen fertilization rate of 50 kg per ha the available potassium level remains the same, and at higher rates of nitrogen it falls even to 81 %. It seems desirable from this point of view to increase potassium levels by higher potassium application rates at a certain ratio to the rates of nitrogen, but in practice this could be done only at nitrogen rates of 150 kg per ha or higher which, unfortunately, is not economically effective. There is no reason to increase the potassium application rates in relation to potassium concentration in herbage (Tab. III). The average contents of 17 to 20 g per kg are more than sufficient. Although it has been traditionally believed that nitrogen acts synergistically on potassium content in herbage, increasing nitrogen application rates were observed to reduce the potassium levels. The highest concentration occurs at a rate of 50 kg of nitrogen per ha and gradually decreases from the first to the last cut. This can be explained on the basis of conclusions published by Matula (1989): though potassium is most active element in plant's uptake, NH_4^+ was demonstrated to be its greatest competitor. In nitrogen supplied by fertilization, about half of it was in the ammonia form, so at a higher concentration it could compete with the K^+ cations.

The dynamics of soil magnesium contents indicates that it decreases when nitrogen is applied at higher rates, i. e. 150 and 300 kg per ha. On the other hand, its concentration in soil increases in the control and at lower nitrogen application rates. If fodder dry matter contents ranging from 1.8 to 2.4 per kg is regarded as sufficient, then the average potassium content in dry matter was more than twice higher than required, particularly in young herbage. All the nitrogen application rates decreased the magnesium concentration in herbage though the decrease was not proportionate to the nitrogen rates. Contrary to this, Jančovič (1982) who used the same fertilization rates found a higher intake of magnesium in the fertilized treatments in comparison with the control. There was a somewhat greater decrease in soil magnesium content in grazed grassland fertilized at a rate of 150 g of nitrogen and a still greater decrease in the herbage of the same grassland, with a decline in magnesium intake by the grazing stock, leading to the danger of grass tetany. Hence, some additional magnesium fertilization of pastures can be recommended in spring.

In comparison with the beginning of the trial (also observed by another author — Tomka, 1976), an increase was recorded in phosphorus reserve. The annual rate of 32 kg of phosphorus per ha was recovered through the "export" of nutrients by harvests in grasslands dressed with up to 300 kg of nitrogen per ha. Where the fertilizer phosphorus was not utilized at nitrogen rates lower than 300 kg per ha (implying lower yields), it will obviously be useful to modify the phosphorus rates with respect to the rates of nitrogen. In this particular case, due utilization ("export" of phosphorus by harvests) would require the following phosphorus application rates: 24 kg P per ha when nitrogen is applied at a rate of 50 kg per ha, 29 kg P per ha when nitrogen is applied at a rate of 150 kg per ha, and 32 kg P per ha when the nitrogen application rate is 300 kg per ha. A similar ratio is given by Novák (1980) who points out that the phosphorus fertilization rate is sufficient when it is just slightly higher than the amount of phosphorus removed from the soil by the stand. In spite of the low to medium phosphorus reserve in the soil, plant analyses indicated that its average concentration was high, ranging from 4.0 to 4.9 per kg. Nitrogen fertilization increased phosphorus concentration in herbage but this was not the case of 300 kg per ha: their effect on phosphorus concentration was either slight or none. The same results were obtained by Jančovič (1982).

The pH value increase slightly, the increase being inversely proportional to the nitrogen rates, so that at a rate of 300 kg of nitrogen per ha the pH is practically the same as the initial pH value. This trend in pH probably follows from the positive balance, which is based on calcium supply (received from fertilizers and precipitation), on calcium removal by harvests and leaching from the soil, and on increasing soil magnesium contents, so there is no reason for soil sweetening. It is also pointed out by Haken (1980) that sweetening of the permanent grasslands is not effective from the viewpoint of production.

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FIALA, J. (Výzkumná stanice Liberec): *Vliv dlouhodobého hnojení dusíkem na koncentraci živin v půdě a píci trvalého travního porostu.* Rostl. Výr., *36*, 1990 (5) : : 519-528.

V letech 1977 až 1987 byla u polopřirozeného travního porostu sledována dynamika přijatelných živin, C_{ox} a pH půdy, jakož i vliv stupňovaných dávek dusíku na koncentraci živin a prvků v sušině píce. Kromě kontroly byly troj- a pětisečné varianty hnojeny fosforem 31,6 kg a draslíkem 66 (83) kg . ha^{-1} stabilně a dusíkem 50, 150 a 300 kg . ha^{-1}. Při stanovení hodnot ukazatelů půdní úrodnosti se ukázala značná závislost na termínu a hloubce odběru. Za těchto podmínek došlo ke zvýšení koncentrace celkového dusíku a přijatelného fosforu na všech variantách. Hodnoty pH a C_{ox} se zvýšily pouze do dávky 150 kg N . ha^{-1} hořčíku do 50 kg N . ha^{-1}, zatímco přijatelný draslík klesal úměrně se zvyšujícími se dávkami dusíku. Stupňované dávky dusíku zvyšují koncentraci vlákniny, dusíku, fosforu a sodíku v sušině píce a koncentrace draslíku se zvyšuje pouze při 50 kg N . ha^{-1} a potom se snižuje. Ke snížení obsahu vlivem dusíkatého hnojení dochází u vápníku a hořčíku.

hnojení dusíkem; přijatelné živiny; živiny v píci; dynamika živin

ФИАЛА, Й. (Научно-исследовательская станция Либерец): **Влияние многолетнего удобрения на концентрацию питательных веществ в почве и зеленые корма многолетнего травостоя.** Rostl. Výr., 36, 1990 (5) : 519-528.

В 1977—1987 гг. у полупродного травостоя исследовали динамику приемлемых питательных веществ, C_{ox} и pH почвы, а также и влияние дифференцированных доз азота на концентрации питательных веществ и элементов в сухом веществе. Кроме контроля три- и пятиукосные варианты удобрялись фосфором 31,6 кг и калием 66 (83) кг . га стабильно и азотом 50, 150 и 300 кг . га. При определении величин показателей почвенной урожайности оказалась значительная зависимость от срока и глубины отбора. При этих условиях наблюдалось повышение концентрации общего азота и приемлемого фосфора у всех вариантов. Величины pH и C_{ox} повысились лишь до дозы 150 кг/га, магния до 50 кг . N/га, причем приемлемый калий понижался соответственно с повышающимися дозами азота. Дифференцированные дозы азота повышают концентрацию клетчатки, азота, фосфора и натрия в сухом веществе зеленого корма, а концентрация калия повышается лишь при 50 кг N . га, а потом понижается. Понижается содержание под влиянием азотного удобрения у известняка и магния.

удобрение азотом; приемлемые питательные вещества; питательные вещества и зеленые корма; динамика питательных веществ

FIALA, J. (Forschungsstation Liberec): *Einfluß langfristiger Stickstoffdüngung auf die Nährstoffkonzentration im Boden und im Futter aus Dauergrünland.* Rostl. Výr., *36*, 1990 (5) : 519-528.

In den Jahren 1977 bis 1987 wurde auf halbnatürlichem Grünland die Dynamik der verfügbaren Nährstoffe, C_{ox} und der pH-Wert des Bodens sowie der Einfluß gesteigerter Stickstoffgaben auf die Konzentration der Nährstoffe und der chemischen Elemente in der Trockensubstanz des Futters untersucht. Abgesehen von der Kontrolle wurden die Drei- bis Fünfschnittvarianten stabil mit Phosporgaben 31,6 kg und Kaliumgaben 66 (83) kg . ha^{-1} sowie mit Stickstoffgaben von 50, 150 und 300 kg . . ha^{-1} gedüngt. Bei der Bestimmung der Werte der Bodenfruchtbarkeitsparameter kam eine beträchtliche Abhängigkeit vom Termin und der Tiefe der Entnahme an den Tag. Unter diesen Bedingungen kam es zu einer Erhöhung der Gesamtstickstoffkonzentration sowie des aufgenommenen Phosphors bei allen Varianten. Die Werte pH und C_{ox} erhöhten sich nur bis zu der Dosis 150 kg N . ha^{-1}, die des Magnesiums bis zu 50 kg N . ha^{-1}, während das verfügbare Kalium mit den steigenden Stickstoffgaben proportional abnahm. Gesteigerte Stickstoffgaben erhöhen die Faserstoff-, Stickstoff-, Phosphor- und Natriumkonzentration in der Trockensubstanz des Futters, die Kaliumkonzentration steigt nur bei 50 kg N . ha^{-1}, um sich dann zu vermindern. Zu einem Rückgang des Gehalts infolge Stickstoffdüngung kommt es bei Kalzium und Magnesium.

Stickstoffdüngung; verfügbare Nährstoffe; des Futters; Nährstoffdynamik

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EFFECTIVENESS OF PHOSPHORUS IN THE NUTRITION OF GRASSLANDS

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KLIMEŠ, F. (University of Agriculture, Praha, Faculty of Agronomy České Budějovice): *Effectiveness of phosphorus in the nutrition of grasslands.* Rostl. Výr., *36,* 1990 (5) : 529-535.

In 1979—1981 in a submontane region of south Bohemia, gradated phosphorus application rates were studied for their effect on change in the yields and quality of the herbage of permanent grasslands treated with different nitrogen application rates and with constant rates of potassium. The herbage yields were statistically highly significantly increased by phosphorus fertilizing only in those cases when nitrogen was applied at a rate of 300 kg per ha. The best yield stability was provided when the grassland was dressed with 200 N + + 40 P + 100 K (V_x = 9.69 %). More phosphorus applied together with more nitrogen increases the productive efficacy of high nitrogen application rates and helps to provide a good quality of the herbage, i. e. to maintain the required phosphorus concentration in the herbage and to decrease the accumulation of NO_3-N in biomass.

permanent grasslands; gradated phosporus application rates; gradated nitrogen rates; herbage yields; herbage quality

In the system of rational grassland management, at sites with adjusted water regime, grass nutrition and fertilization are a basic prerequisite for a favourable stand composition as well as for the required quantitative and qualitative aspects of herbage production (Klesnil, Turek, 1975). The grasslands respond dynamically, especially to nitrogeneous nutrition; nevertheless, only full NPK-nutrition (Klapp, 1971; Turek, 1973; Haken et al., 1981; Velich, 1986; Ramon, 1986 and others) is considered as rational.

Phosphorus fertilization acts favourably on the botanic changes in the stands and on herbage quality (Klesnil, Turek, 1975). A minimum of 0.3 % of phosphorus should be contained in the dry matter of good-quality herbage at adequate yields. A sufficient phosphorus content in the herbage at which the yield is not limited by phosphorus deficit also corresponds to the requirements for rational nutrition of cattle (Petřík et al., 1987). Phosphorus concentration in the herbage varies in a wide range (from 0.1 to 0.45 % in dry matter), though it is usually lower in the grassland than required for animal nutrition (Haken et al., 1981). Phosphorus is next to nitrogen as for its importance for yield formation in the grasslands (Habovštiak, 1972). It often happens, owing to the phosphorus in the soil, that the effect of phosphorus is poor at the beginning and as a rule several years must have elapsed before this effect can manifest itself fully (P e t ř í k et al., 1987).

Effects of gradated phosphorus application rates were studied, as exerted on the effectiveness of phosphorus in the formation of the quantitative and qualitative traits of the output in permanent grasslands treated at different intensities with nitrogen fertilizing.

MATERIALS AND METHODS

In the years 1979—1981, the effects of gradated nitrogen and phosphorus application rates, together with constant potassium application rates, on the yield changes and on herbage quality in permanent grasslands were studied at two sites in the submontane and montane regions of the Šumava Mts. (Tab. I). The stands under study belong to the range of the association of *Arrhenatheretum elatioris* BRAUN BLANQUET 1919, stand type *Trisetetum*. The stands were cut twice in four replications. The following forms of fertilizers were used: LAV_{30}, SP_{18}, DS_{60}. Phospohorus and potassium were applied every year in spring. Nitrogen was provided through a single application up to a total rate to 100 kg per ha applied in spring, but higher nitrogen rates were divided: 200 kg (150 + 50), 300 kg (200 + 100).

I. Ecological characteristics of the sites under study

Site	Altitude above s. l.	Average air temperature (°C)	Year precipitation sum (mm)	pH_{KCl}	Contents of main nutrients in sward layer of soil (mg per kg of soil)		
					P	K	Mg
S_1	545	6.3	675	6.5	8	47	110
S_2	704	6.2	683	7.0	7	42	105

The herbage yields were determined at harvest and were converted to hay yield (at 85 % of dry matter). Samples were taken for the determination of herbage quality. The samples were chemically analysed by methods prescribed by the Central Agricultural and Testing Institute.

The yield results were evaluated by correlation and regression analyses with verification of a suitable type of yield curve for determination of the relationship between nitrogen rate and herbage yield at separate phosphorus application rates (P_0 — treatment 2 to 6; P_{20} — treatment 7 to 11; P_{04} — treatment 12 to 16). The variability of yields was also evaluated by variation coefficients (V_x in %) in each treatment. Of the qualitative characteristics, phosphorus and NO_3-N concentrations in herbage are evaluated along with the rations of P : Ca and (Ca : Mg) : K. Weighted arithmetical means were determined as the mean values for each component of the herbage. The changes in phosphorus concentrations were evaluated using individual basic indexes. Evaluating the NO_3-N concentration in herbage, 99 % — 100P% quantiles were also determined as characteristics of probability (K l i m e š, 1985).

RESULTS AND DISCUSSION

It follows from comparisons of the obtained herbage yields (Tab. II) that phosphate fertilization provided a statistically highly significant increase in herbage yields only at the highest nitrogen application rate under study (300 kg per ha). When the combination of 300 N + + 20 P + 100 K (treatment 11) was used, the highest productive effecti-

II. A survey of the tested combinations of nutrition and average yields of hay (at 85 % of dry matter). Yield variability expressed by the variation index V_x (%)

Treatment	Set	Rate pure of nutrients (kg per ha)			Average hay yield (in t per ha)	V_x (%)
		N	P	K		
1		0	0	0	4.538	21.56
2		0	0	100	3.952	16.33
3		50	0	100	5.750	13.49
4	P_0	100	0	100	6.914	18.38
5		200	0	100	8.457	18.01
6		300	0	100	8.443	19.46
7		0	20	100	4.782	28.33
8		50	20	100	5.718	23.16
9	P_{20}	100	20	100	6.775	15.29
10		200	20	100	8.675	15.34
11		300	20	100	10.161	20.61
12		0	40	100	4.817	15.46
13		50	40	100	5.265	24.46
14	P_{40}	100	40	100	6.930	17.66
15		200	40	100	9.162	9.69
16		300	40	100	9.635	18.82

$d_{0.05} = 0.696$; $d_{0.01} = 0.916$

veness of 1 kg of phosphorus was obtained (yield increase 85.9 kg of hay per kg of phosphorus). The effect of phosphorus application on the yields was more or less indifferent at nitrogen application rates of 50 to 100 kg per ha. However, phosphorus appears to influence the production efficacy of nitrogen through the phosphorus-nitrogen interaction rather than through the action of phosphorus alone (H a b o v š t i a k, 1972; P e t ř í k et al., 1987).

A shift of the minimum level of the relative herbage yield variability towards higher nitrogen application rates is seen from comparisons of the determined values of this important production trait at gradated phosphorus application rates. In stands without phosphorus application the lowest yield variability was recorded when nitrogen was applied at a rate of 50 kg per ha. At a phosphorus application rate of 20 kg per ha the yield variability was the lowest at a nitrogen rate of 100 kg per ha, and at the highest phosphorus rate under study, 40 kg per ha, the lowest yield variability was recorded only at a rate of 200 kg of nitrogen per ha; this, in fact, was the lowest yield variability of all ($V_x =$ $= 9.69$ %).

There is certain coincidence with the values of productive effectiveness of nitrogen: in treatments with the lowest values of yield variability (within separate sets with different rates of phosphate fertiliz-

III. Weighted arithmetical means of phosphorus concentration in herbage (in % of absolute dry matter); dynamics of phosporus concentration changes expressed by means of individual basic indexes (IIB)

Treatment	Set	Year			$\bar{x}$	IIB (%)	
		1979	1980	1981		80/79	81/79
1		0.263	0.280	0.272	0.271	106.46	103.42
2	P_0	0.279	0.301	0.309	0.295	107.89	110.75
3		0.272	0.267	0.242	0.262	98.16	88.97
4		0.271	0.280	0.252	0.269	103.32	92.99
5		0.244	0.256	0.231	0.244	104.92	94.67
6		0.214	0.229	0.208	0.218	107.01	97.20
7	P_{20}	0.284	0.337	0.333	0.312	118.66	117.25
8		0.275	0.335	0.346	0.313	121.82	130.91
9		0.269	0.308	0.295	0.290	114.50	109.66
10		0.256	0.317	0.280	0.282	123.83	109.38
11		0.264	0.299	0.250	0.273	113.26	94.70
12	P_{40}	0.311	0.381	0.369	0.352	122.51	118.65
13		0.293	0.328	0.371	0.324	111.95	126.62
14		0.280	0.367	0.367	0.332	131.07	131.07
15		0.292	0.339	0.338	0.322	116.10	115.75
16		0.265	0.321	0.334	0.304	121.13	126.04

ing), the highest productive effectiveness was recorded, representing an average yield increment of 35.96 kg of hay per 1 kg of nitrogen at a rate of 50 N + 100 K, 19.93 kg at a rate of 100 N + 20 P + 100 K, and 21.73 kg at a rate of 200 N + 40 P + 100 K. At the same time, the lowest productive effectiveness of 1 kg of NPK (yield increment of 13.60 kg of hay per kg of NPK) was recorded in the combination of 200 N + 40 P + 100 K.

Mutual interaction of nitrogen and phosphorus influenced even the patterns of the production functions, expressing the relationship between the nitrogen rate (x in kg per ha) and the hay yield (y in kg per ha) as can be seen in separate application rates (P_0 — treatment 2 to 6; P_{20} — treatment sets, differing in their phosphorus rates.

$$P_0 : y' = 3974 + 38x - 0.000{,}018x^3 \quad [I_{yx} = 0.834^{++}]$$
$$P_{20} : y' = 4774 + 19x + 0.018x^2 - 0.000{,}068x^3 \quad [I_{yx} = 0.825^{++}]$$
$$P_{40} : y' = 4746 + 8x + 0.162x^2 - 0.000{,}447x^3 \quad [I_{yx} = 0.862^{++}]$$

In the P_0 set a production function exhibits a degressive course, analogous with the course reported by Velich (1986) and Haken, Kvítek (1988) as the prevailing course of the yield curve which Velich (1986) designated as the mineralization type. Transition to the progressive-degressive type, i. e. type of immobilizing nature, is

IV. NO_3^--N concentration in herbage (y — weighted arithmetic mean, $y_{0.99}$ — 99% 100P% quantiles) and average values Ca : P and K : (Ca + Mg) ratios

Treatment	Set	NO_3^--N (% in absolute dry matter)				Ca : P	K : (Ca+Mg)
		y	y_{min}	y_{max}	$y_{0.99}$		
1		0.059	0.027	0.108	0.128	3.700	1.708
2	P_0	0.035	0.011	0.101	0.109	3.318	2.091
3		0.036	0.019	0.088	0.096	2.737	2.542
4		0.087	0.031	0.302	0.334	2.948	2.441
5		0.082	0.026	0.176	0.201	2.871	2.574
6		0.147	0.055	0.300	0.361	3.053	2.505
7	P_{20}	0.031	0.015	0.068	0.075	3.005	2.046
8		0.033	0.016	0.066	0.075	2.558	2.375
9		0.037	0.021	0.071	0.081	2.900	2.261
10		0.140	0.031	0.462	0.512	2.299	2.765
11		0.264	0.062	0.405	0.676	2.576	2.465
12	P_{40}	0.074	0.019	0.172	0.204	2.587	2.072
13		0.043	0.030	0.065	0.073	2.980	2.045
14		0.052	0.028	0.097	0.110	2.431	2.424
15		0.070	0.016	0.130	0.165	2.069	2.452
16		0.193	0.117	0.366	0.447	2.086	2.555

obvious in the P_{20} and P_{40} sets, the P_{20} set being slightly inclined to the linear (transitive) type; hence, gradated phosphorus application rates can be considered as being actively involved in the process of increasing the biological immobilization of nitrogen.

The process of gradual saturation of hay with phosphorus (Lichner et al., 1977) is indicated by changes of phosphorus concentration in herbage, particularly at a higher level of phosphorus fertilization (P_{40}, Tab. III). At the same time it can be seen that the higher nitrogen rates, the lower phosphorus concentration in herbage. Hence, it is useful to increase proportionately the rates of phosphorus when nitrogen fertilizers are applied at high rates (Klimeš, 1985).

It is seen from the determined values of NO_3-N concentration that with suitable combination of nitrogen and phosphorus fertilization, phosphorus can help to slow down effectively the growth of nitrate concentration in herbage at gradated nitrogen application rates. Within the P_0 set, the average value of NO_3-N concentration in herbage did not exceeded 0.07 % in absolute dry matter at nitrogen application rates up to 50 kg per ha, in the P_{20} set up to a nitrogen application rate of 100 kg per ha and, in the P_{40} set even up to 200 kg per ha.

It follows at the same time from the values of 99% 100P% quantiles (Tab. IV) that the above-mentioned nitrogen application rates and corresponding levels of phosphorus application theoretically provide a minimum 99% probability of not exceeding, with such application rates, the threshhold of potential toxicity (0.20 % NO_3-N in absolute dry matter). The lowest probability exceeding the NO_3-N concentration in individual cases above the value characterizing absolutely safe herbage (0.07 % NO_3^--N in absolute dry matter) is provided at an application rate of 50 N + 40 P + 100 K (Klimeš, 1985) at which, at the same time, the lowest value of the (Ca + Mg) : K (1 : 2.045) was recorded. On the other hand, from the point of view of the P : Ca ratio in herbage, the combination of 200 N + 40 P + 100 K appears most suitable: in that case the mentioned ratio was 1 : 2.069.

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KLIMEŠ, F. (Vysoká škola zemědělská, Praha, agronomická fakulta České Budějovice): *Uplatnění fosforu ve výživě travních porostů.* Rostl. Výr., *36,* 1990 (5) : 529-534.

V letech 1979 až 1981 byly v podhorské oblasti jižních Čech ověřovány stupňované dávky fosforu na změny výnosů a kvality píce u trvalých travních porostů s aplikací různě vysokých dávek dusíku při konstantní úrovni draselného hnojení. Fosforečné hnojení zvyšovalo statisticky vysoce významně výnosy píce pouze při dávce dusíku 300 kg . ha^{-1}. Nejvyšší výnosová stabilita je zajišťována při aplikaci 200 N + + 40 P + 100 K (V_x = 9,69 %). Zvyšování dávek fosforu při růstu intenzity hnojení travních porostů dusíkem se ukazuje jako předpoklad lepšího produkčního uplatnění vyšších dávek dusíku a napomáhá též k zabezpečení dobré kvality píce zejména s ohledem na požadovanou koncentraci fosforu v píci a na snižování akumulace NO_3-N v biomase.

trvalé travní porosty; stupňované dávky fosforu; stupňované dávky dusíku; výnosy píce; kvalita píce

КЛИМЕШ, Ф. (Сельскохозяйственный институт, Прага, агрономический факультет Чешске Будейовице): **Применение фосфора в питании травостоев.** Rostl. Výr., *36,* 1990 (5) : 529-534.

В 1979—1981 гг. в подгорных областях южной Чехии обследовали дифференцированные дозы фосфора влияющие на изменения урожаем и качество зеленого корма у многолетних травостоев с применением разных высоких доз азота при константном уровне калийного удобрения. Фосфорное удобрение повышало статистически значительно урожаи зеленого корма лишь при дозе азота 300 кг/га. Самая высокая стабильность была определена при внесении 200 N + 40 P + 100 K (V_x = 9,69 %). Повышение доз фосфора при росте интенсивности удобрения травостоев азотом оказывается предпосылкой лучшего продукционного внедрения более высоких доз азота и помогает, также, обеспечению хорошего качества зеленого корма, главным образом, с учетом требуемой концентрации фосфора в зеленом корме и понижения аккумуляции NO_3-N в биомассе.

многолетние травостои; дифференцированные дозы фосфора; дифференцированные дозы азота; урожаи зеленых кормов; качество зеленого корма

KLIMEŠ, F. (Landwirtschaftliche Hochschule, Praha, agronomische Fakultät České Budějovice): ***Betätigung von Phosphor in der Ernährung von Grünland.*** Rostl. Výr., *36,* 1990 (5) : 529-534.

In den Jahren 1979 bis 1981 wurden in einem südböhmischen Vorgebirgsgebiet Auswirkungen gesteigerter Phosphorgaben auf Veränderungen der Erträge und der Qualität des Futters aus Dauergrünland mit einer Applikation verschieden hoher Stickstoffgaben bei konstantem Niveau der Kaliumdüngung getestet. Die Phosphordüngung erhöhte statistisch hochsignifikant die Erträge der Futterpflanzen nur bei der Stickstoffdosis von 300 kg . ha^{-1}. Die höchste Ertragsstabilität ist bei der Applikation von 200 N + 40 P + 100 K (V_x = 9,69 %) sichergestellt. Eine Erhöhung der Phosphordosen bei steigender Intensität der Stickstoffdüngung der Gräserbestände erweist sich als Voraussetzung einer besseren Produktionsbetätigung höherer Stickstoffgaben und hilft auch der Sicherstellung einer guten Qualität des Futters, insbesondere in Hinsicht auf die geforderte Phosphorkonzentration im Futter und auf die Herabsetzung der NO_3-N-Akkumulation in der Biomasse.

Dauergrünland; gesteigerte Phosphordosen; gesteigerte Stickstoffdosen; Futtererträge; Futterqualität

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REVIEW

DIE SAUERGRÄSER — SCHLÜSSEL ZU IHRER BESTIMMUNG IM BLÜTENLOSEN ZUSTAND

SOUR GRASSES — KEY TO THEIR IDENTIFICATION IN FLOWERLESS STAGE

A. Petersen, W. Petersen, G. Wacker

Berlin, Akademie Verlag, 1989, 91 pp., 6 figs, 6 tables

This is the work of the world-known specialist in the field of botanics and production of the grass communities. It is a continuation of his previous works: *Clover and other species of clover family as cultivated crops, Wild plants and weeds in fields and grasslands, Grasses as cultivated plants and weeds in grassland and fields.* Prof. Asmus Petersen had long worked for Research Institute of grasslands and peat at Paulinenau near Berlin. The presented work was reviewed by his former pupil and colleague Prof. G. Wacker.

Sour grasses of the family *Cyperaceae,* including the genera *Scirpus, Eriophorum* and *Carex* are distributed all over the world and represent about, 3,700 species. Their main morphological traits, in which they differ from economically important grass species, are analysed in the introductory part.

The second part of the book contains, in fact, the key to the identification of the genera and their species on the basis of the morphological pecularities of the leaves, stems and roots. The third, most important part of the book deals with the feeding value of each genus and species, with the site conditions under which they are maintained in the natural environments, and with the various methods of their control. From this point of view they are divided into the grasses of damp sites, those of common mediocre grassland communities, those of dry regions, those of mountain and Alpine regions, forest associations and salinized soils.

As to their feeding value, attention is drawn to the comparatively high yields of some species *(Carex gracilis, Carex acutiformis, Phalaris arudinacea, Phragmatis australis, Molinia caerulea),* which, under specific conditions, may even be of economic use. Otherwise, they play an important conservation role in natural conditions. They are fairly easy to control, mainly at damp sites, where drainage is essential prerequisition. In many cases fertilization alone will suffice to convert them into good meadows or pastures, because the valuable grass species usually react to this treatment well enough to suppress, by their biological activity, the shorter species of vigorous sour grasses. Every-year mowing is very important. Tillage and adjustment of water conditions are recommended in some cases.

The book is intended for the experts in grassland management, land improvement conservation, forestry, etc.

Ing. Jozef Habovštiak, CSc.

POSSIBILITIES TO USE CATTLE SLURRY IN GRASSLAND NUTRITION

Z. Vahala

VAHALA, Z. (Research Station Jevíčko): *Possibilities to use cattle slurry in grassland nutrition.* Rostl. Výr., *36*, 1990 (5) : 537-546.

Experiments were conducted on alluvial soil in a beet growing area, climatic region MT-2, 340 m above sea level, to study various methods of using cattle slurry in permanent grasslands. In the first experiment, slurry nitrogen was found to have a lower effectiveness when slurry was applied every year onto grass surface or into the sward; the difference from the control (nitrogen applied in mineral fertilizers) was 13 %. With alternating application (one year slurry, next year mineral fertilizer), the decrease in comparison with the control was by 2 to 3 %. In the second trial, slurry was incorporated in the soil during pre-seeding preparation in the express renovation of permanent grassland, the nitrogen rates being 150, 300, and 450 kg per ha. Dry matter output was increased highly significantly by 5.1 to 10.4 %, on an average for five years, in comparison with control. Applied slurry had a long-term action which increased dry matter output by 5.3 % in the first year, by 12.4 % in the second year, by 15.6 % in the third year, by 4.4 % in the fourth year, and by 4.7 % in the fifth year (on an average for the slurry application rates). In the third trial, increased introgen amounts were applied during soil cultivation when the grassland was renovated (225 kg per ha in slurry or in mineral fertilizers). This reduced the proportion of *Trifolium pratense* (Kvarta variety) by 5.6 % in the first harvest year and by 18 % in the second year. The proportion of *Trifolium pratense* was also reduced by nitrogen applied in the first and second harvest year.

permanent grassland; cattle slurry; nutrition; express grassland renovation

The development of the litterless system of cattle housing on large farms has introduced the production of slurry in all types of production regions; this in turn has raised the problem of its suitable and rational use. The most widespread of the use of slurry is application onto the surface of grassland. Tomka, Hrivnák (1969) and Tomášík (1984) observed that the nitrogen of the slurry applied in this way has a lower efficacy than that applied in mineral fertilizers. Nágl (1955) and Škarda (1978) recommend to apply 12 to 160 tonnes of slurry per 1 ha, the total amount being divided into two to three batches applied during the year. The best time to apply slurry to permanent grassland — as Fryček (1965) asserts — is after the first cut in spring. The total slurry application rates are determined according to the contents of nitrogen or potassium. Sladovník (1964) and Nágl (1955) explain that slurry application rates should be determined with respect to potassium content because grassland has a tendency toward luxury consumption of potassium, thus herbage of poorer quality. The

I. Characteristics of the climatic conditions of the experimental site

Year	Average temperature (°C)		Precipitation sum (mm)	
	annual	for growing season	annual	for growing season
1981	7.1	13.0	613.2	295.0
1982	8.0	14.4	376.7	256.0
1983	8.2	14.1	412.1	244.6
1984	7.5	12.9	446.3	322.0
1985	4.6	11.7	514.5	396.7
1986	5.9	12.9	541.5	325.0
1987	4.7	11.3	548.5	391.1
1988	6.9	12.5	504.3	295.2
$\bar{x}$ za 50 let	7.5	13.9	629	397.0

reason why the content of nitrogen is used for the determination of slurry application rates is the effort for reaching optimum yields of herbage. This view is corroborated, as Š k a r d a (1978) observed, that increased slurry application rates do not increase NO_3^--N content in herbage so much as does the application of mineral nitrogen fertilizers.

Cattle slurry containing 0.30 % nitrogen and 0.24 % potassium can be characterized as a nitrogen-potassium fertilizer. It also contains phosphorus (0.07 %) and other nutrients in its organic matter, and its biological activity is high. The objective of our investigation was to identify the possibilities of non-traditional use of cattle slurry.

MATERIALS AND METHODS

Possibilities to use cattle slurry in the manuring of grassland were explored in three experiments. These experiments were conducted in a beet growing region 340 m above sea level, in the MT-2 climatic region characterized as slightly warm and slightly humid. The sums of the temperature of 10 °C and above 10 °C range between 2200 and 2500 °C, the probability of occurrence of dry growing seasons is 15 to 30, moisture security is from 4 to 10, average annual temperature 7 to 8 °C,

II. Chemical composition of the soil to a depth of 0.20 m

	Experiment			
	1	2	3	
Total N (%)	0.196	0.190	0.215	after Kjehldahl
P (mg/1000 g)	6.7	10.5	55.0	after Egner
K (mg/1000 g)	201.5	53.5	64.0	after Schachtschabel
pH	6.43	6.65	6.6	active
Humus (%)	2.75	2.57	3.04	after Tjurin

III. Experimental treatments (first trial)

Treatment	Fertilizer	Application	Nutrients supplied during four years		
			N	P	K
C	mineral		300	26.4	66.4
2	cattle slurry	every year into sward	300	65.9	251.3
3	cattle slurry	every year into surface	300	65.9	251.3
4	cattle slurry	1st year into sward 2nd year mineral fertilizer	300	32.6	109.2
5	cattle slurry	1st year onto surface 2nd year mineral fertilizer	300	32.6	109.2

fifty-year precipitation normal 550 to 750 mm. The clinical conditions during the experiments are surveyed in Tab. I. The soil of the experimental plots was alluvial sandy loam. Its chemical composition is shown in Tab. II. The ground water table was out of plant roots' reach during the experiments. The grassland was harvested in a three-cut system.

The first experiment was started in 1981 and comprised five treatments (Tab. III).

The nitrogen application rate was the same in all treatments: 300 kg per ha. Slurry was applied either every year or in an alternating way (first year slurry, next year mineral fertilizers). The total batch of 300 kg per ha was divided into 150 kg applied in spring and another 150 kg applied after the firts cut.

The second trial was started on three dates in 1982: in spring, after the first cut, and after the second cut. The objective of the experiment was to explore the possibilities of using cattle slurry for express grassland renovation in different periods of the growing season. Slurry was applied onto newly ploughed sward at different nitrogen application rates: 150, 300, and 450 kg per ha. Twenty-four hours later it was incorporated into the soil by means of a rotavator. The experimental plot was sown with a clover-grass mixture including *Dactylis glomerata* (Milona) — 30 kg, *Trifolium pratense* (Kvarta) — 4.80 kg, *Trifolium repens* (Huia) — 3.60 kg per ha. The experimental treatments are surveyed in Tab. IV.

IV. Experimental treatments (second trial)

Treatment	Fertilization in year of establishment				Fertilization in subsequent years (mineral fertilizers)				
	fertilizer	N	P	K	1983	1984	1985	1986	1987
0	mineral	150	26.4	66.6	150	200	250	250	250
2	slurry	150	32–42	120–159	150	200	250	250	250
3	slurry	300	64–84	240–318	150	200	250	250	250
4	slurry	300	64–84	240–318	50	200	250	250	250
5	slurry	450	95–126	360–477	50	200	250	250	250

Division of nitrogen application rate in subsequent years: 150 kg = 100 + 50
200 kg = 100 + 50 + 50
250 kg = 120 + 70 + 60

Phosphorus and potassium fertilization:
contro treatment: 26.4 kg P and 66.4 kg K per 1 ha
treatments 2, 3, 4, 5: up to the same nutrition level as in the control (C) — treatment

V. Experimental treatments (third trial)

Block	Fertilizer	Treatment	Fertilization in starting year			Nitrogen fertilization (mineral fertilizers) in subsequent years					
						1987			1988		
						cut					
			N	P	K	1st	2nd	3rd	1st	2nd	3rd
A	mineral fertilizers	1	60	35.2	100	–	–	–	–	–	–
		2	60	35.2	100	60	–	–	60	–	–
		3	60	35.2	100	60	60	–	60	60	–
B	cattle slurry	4	233	100	364	–	–	–	–	–	–
		5	233	100	364	60	–	–	60	–	–
		6	233	100	364	60	60	–	60	60	–
	mineral fertilizers	7	233	100	364	60	–	–	60	–	–

Phosphorus and potassium fertilization in 1987 and 1988:
- block A: 35.2 kg P and 100 kg K per 1 ha
- block B: up to the same levels as in block A

The third trial was conducted in 1986 in two blocks. Cattle slurry was used for basic grassland fertilization in block B at a nitrogen application rate of 225 kg per ha. Block A was used for comparison: mineral fertilizers (60 kg N, 35.2 kg P, 100 kg K per ha) were used for the basic nutrition of the stand. Clover-grass mixture of *Dactylis glomerata* (Niva) — 22.0 kg, *Poa pratensis* (Rožnovská) — 3.0 kg, *Trifolium pratense* (Kvarta) — 5.0 kg, *Trifolium repens* (Dúbrava) — 3.0 kg per ha was used for the renewal of the grassland. The experimental treatments are shown in Tab. V.

VI. Dry matter output (average for four years, first trial)

Treatment	Fertilizer	N application rate	Dry matter output (t per ha)	%
C	mineral fertilization	300	11.736	100
2	slurry applied into sward every year	300	10.192	86.8
3	slurry applied onto surface every year	300	10.167	86.6
4	1st year: slurry into sward 2nd year: mineral fertilization	300	11.386	97.0
5	1st year: slurry onto surface 2nd year: mineral fertilization	300	11.505	98.0
P 0.05			0.454	
P 0.01			0.605	

VII. Dry matter output in t per ha (second trial)

Treatment	Fertilization in year of establishment		Dry matter output ($\bar{x}$ 1983–1987) according to the time of establishment			$\bar{x}$	%
	fertilizer	N rate (kg per ha)	spring	after 1st cut	after 2nd cut		
C	mineral	150	10.788	11.159	11.039	10.992	100
2	cattle slurry	150	11.284	11.804	11.722	11.603	105.6
3	cattle slurry	300	11.724	11.937	12.127	11.929	108.5
4	cattle slurry	300	12.112	12.309	11.995	12.136	110.4
5	cattle slurry	450	12.032	11.988	12.265	12.095	110.0
P 0.05				0.400		0.229	
P 0.01				0.526		0.301	

RESULTS

In the first trial, on a four-year average, the highest dry matter output (Tab. VI) was obtained in the every-year treatment with mineral fertilizers (11.736 tonnes per ha). The lowest dry matter output was obtained in the treatment where the grassland was manured every year with cattle slurry either by surface application or with incorporation into the sward. The differences from the treatments with mineral fertilizers (13.2 to 13.4 %) are highly significant. The alternating treatments (one year slurry, next year mineral fertilizers) had an insignificantly lower otput of dry matter (by 2 to 3 %) in comparison with the control. Comparing the treatments which alternating and every-year application of slurry (both onto surface and into the sward) it can be seen that the differences of 11.7to 13.1 % are highly significant in favour of the alternating treatment. There was no significant difference between

VIII. Subsequent effectiveness of cattle slurry (second trial)

Treatment		Year 1983	1984	1985	1986	1987
C	t per ha	13.081	9.294	12.465	10.098	10.036
	%	100	100	100	100	100
2	%	104.8	105.7	110.8	104.0	101.3
3	%	107.1	110.4	115.2	102.7	116.0
4	%	104.7	116.3	117.6	106.7	107.2
5	%	104.7	117.3	118.8	101.7	104.6
$\bar{x}$ 2–5	%	105.3	112.4	115.6	104.4	104.7

IX. Dry matter output in t per ha (third trial)

Block	Treatment	Year			$\bar{x}$
		1986	1987	1988	
A – mineral nutrition	1, 2, 3	9.180	14.995	13.254	12.476
B – slurry	4, 5, 6	10.494	15.875	11.122	12.497
P 0.05		0.471	0.312	0.741	0.218
P 0.01		0.864	0.572	1.361	0.289

the surface application of slurry onto the grass and incorporation of slurry into the sward.

The second trial lasted five years and was aimed at investigating the effectiveness of cattle slurry used for the basic nutrition of a permanent grassland subjected to express renewal. In comparison with treatments using mineral fertilizers, the use of slurry provided highly significantly greater dry matter yields at all times of stand establishment (Tab. VII). Slurry application rates up to 300 kg nitrogen per ha were the best: in treatment 4 this application rate provided the highest dry matter output. Further increase of slurry application rates (450 kg per ha) failed to bring about the required effect. Slurry used for basic stand nutrition in express regeneration has a long-persistent effect (Tab. VIII). In the first harvest year slurry increased dry matter output by 5.3 %, in the second harvest year by 12.4 %, in the third by 15.6 %,

X. The weight percentage $\bar{x}$ of *Trifolium pratense* in the experimental years

Block	Treatment	Total N rate for three years	*Trifolium pratense*				Dry matter output (t per ha) $\bar{x}$ 1986–1988
			1986	1987	1988	$\bar{x}$ 1986–1988	
A	1	60	12.6	25.9	44.5	29.29	12.452
	2	180	7.9	25.2	40.1	26.0	12.446
	3	300	8.9	21.1	39.8	24.49	12.532
	$\bar{x}$		9.79	24.05	41.47	26.72	
B	4	233	11.7	16.3	32.6	19.90	12.339
	5	353	13.6	24.1	21.5	20.40	12.448
	6	473	12.0	16.5	16.4	15.23	12.644
	$\bar{x}$		12.43	18.99	23.48	18.49	
	7	353	6.4	18.2	29.9	18.9	12.114
P 0.05							0.356
P 0.01							0.473

in the fourth by 4.4 %, and in the fifth by 4.7 %, in comparison with treatments using mineral fertilizers, on an average for treatments 2 to 5.

Two blocks with different forms of fertilizers, used during grassland renewal, were studied in the third trial. Mineral fertilizers were used in block A, cattle slurry was used in block B. Further nutrition was the same in both blocks and different application rates of mineral fertilizers were used. Cattle slurry proved to be effective only in 1986 and 1987 when the dry matter yields in the slurry-treated block were highly significantly greater. In 1988 the reverse was the case, so in general the dry matter output was about the same in both blocks (on an average for the whole experiment). The use of high nitrogen application rates, supplied in slurry in the year of renewal, reduced the proportion of *Trifolium pratense* in the grassland in the first harvest year by 5 % and in the second harvest year by 18 %. On an average for three years this reduction amounted to 8.23 % (Tab. IX). Treatment 7 where mineral fertilizers were used at similar NPK application rates in the year of establishment showed a similar decline of the proportion of *Trifolium pratense* as did treatment 5, fertilized with the same amounts of nitrogen, phosphorus and potassium in slurry at establishment. The adverse effect of nitrogen application upon the proportion of *Trifolium pratense* in the stand was observed also in the subsequent years in both blocks (Tab. X). Every-year application of 120 kg nitrogen per ha reduced the weight proportion of red clover in the herbage by 5 %, on an average. In the subsequent years, increased nitrogen application rates failed to increase significantly the output of dry matter.

DISCUSSION

The experiments were conducted to test the methods of utilization of cattle slurry for grassland manuring. When slurry was applied in the traditional way onto grass surface, the nitrogen contained in the slurry had a significantly lower effectiveness than when mineral fertilizers were used. Our results confirm what is asserted by some authors (Fryček, 1965; Tomek, Hrivnák, 1969; Sladovník, 1964; Tomášík, 1984): The lower effect of slurry nitrogen is considered to be due to evaporation which depends on the conditions and date of application. Similar results were obtained when slurry was applied into the sward by means of special shares.

Alternating application of slurry (one year cattle slurry, next year mineral fertilization) appears to be better. In this system the output of dry matter was just insignificantly lower than with the use of mineral fertilizers; this confirms the results published by Královec, Rais (1981). Alternating use of slurry also eliminates the hazard of overmanuring the grassland with phosphorus and, particularly, potassium.

The best method of slurry application is to incorporate it into the soil during pre-seeding preparation when the grassland is subjected to express renewal. During the five years of the second experiment, all the slurry application rates increased the average annual output of dry matter by 5.6 to 10.4 % in comparison with the treatments with mineral fertilizers. Slurry has a generally favourable effect. In well aerated soil it acts as an inoculating material encouraging microbial activity whose development largely depends on soil temperature and moisture, on nitrogen supply, on the amount of organic matter and on other factors (Škarda, 1978). Intensified mineralizing activity of the microbes produces nitrogen compounds as available plant food (Pokorná — Kozová, 1979). The slurry application rates used during express grassland renewal should be determined not only according to the content of potassium, but also nitrogen, because amounts of nitrogen above 300 kg per ha fail to produce any further yield effect; moreover, they suppress the clover component of the grass-clover mixtures. The results of experiment 3 clearly indicate (Tab. X) that even the lower amount of 225 kg of slurry nitrogen per ha, applied during establishment, affected the proportion of *Trifolium pratense* in the stand. Nor was there any increase in dry matter output (in comparison with unfertilized control) when high nitrogen application rates were used in the subsequent years; a further reduction of the proportion of red clover was recorded in these cases. The supplied nitrogen probably offset the loss of microbial nitrogen fixed by the Kvarta variety of *Trifolium pratense*. Hence, if *Trifolium pratense* is to be maintained in the grassland as long as possible, the nitrogen application rates in slurry should be reduced to 60 to 150 kg per ha in the year of renewal. The adverse effect of nitrogen fertilization on the proportion of clovers is described by Neuberg et al. (1985) who recommended to reduce nitrogen application rates to keep clover in the stand. In their view, slurry could be applied during renewal at rates of up to 350 kg nitrogen per ha.

If output is compared in block A (minerals applied during renewal) and block B (slurry) (Tab. X), a significant difference in yields will be observed only in the year of establishment and in the first harvest year. In the subsequent year the output was highly significantly lower in the slurry block so that the average yields for the three years of the trial were about the same in both blocks. This was due to the fact that *Trifolium pratense* was suppressed in the stand by the high amounts of nitrogen contained in the liberal application rates of slurry. All this clearly suggests that nitrogen in slurry can be applied at high rates only when grasslands are established without *Trifolium pratense*.

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VAHALA, Z. (Výzkumná stanice Jevíčko): *Možnosti využití hovězí kejdy pro výživu travních porostů.* Rostl. Výr., *36*, 1990 (5) : 537-546.

V klimatickém regionu MT-2 na nivní půdě v řepařské výrobní oblasti v nadmořské výšce 340 m jsme sledovali různé způsoby využití hovězí kejdy na travních porostech. V prvním pokuse byla zjištěna nižší účinnost dusíku dodaného v hovězí kejdě při její každoroční aplikaci na povrch nebo do drnu travních porostů o 13 % oproti kontrolní variantě, hnojené minerálními hnojivy. Při střídavé aplikaci (jeden rok kejda, druhý rok minerální hnojivo) bylo zjištěno snížení o 2 až 3 %. V druhém pokuse při zapravení kejdy do půdy v době předseťové přípravy při rychloobnově trvalých travních porostů v dávkách dusíku 150, 300, 450 kg . ha^{-1} bylo zjištěno vysoce průkazné zvýšení produkce sušiny o 5,1 až 10,4 % v průměru pěti let oproti kontrolní variantě. Projevilo se dlouhodobé působení hnojení kejdou, které příznivě zvyšovalo produkci sušiny v prvním roce o 5,3 %, v druhém roce o 12,4 %, ve třetím roce o 15,6 %, ve čtvrtém roce o 4,4 % a v pátém roce o 4,7 %, v průměru dávek kejdy. Ve třetím pokuse zvýšené dávky dusíku dodané v době přípravy půdy při obnově (a to v kejdě nebo v minerálních hnojivech 225 kg . ha^{-1}) způsobily snížení zastoupení *Trifolium pratense* odrůdy Kvarta v prvním užitkovém roce o 5,6 % a v druhém užitkovém roce o 18 %. Na snižování zastoupení *Trifolium pratense* působily i dávky dusíku aplikované v prvním a druhém užitkovém roce.

trvalé travní porosty; hovězí kejda; výživa; rychloobnova

ВАГАЛА, З. (Научно-исследовательская станция Евичко): **Возможность использования навоз скота для питатния травостоев.** Rostl. Výr., *36*, 1990 (5) : 537-546.

В климатическом регионе МТ-2 на аллювиальной почве в свекловичной производственной области при высоте 340 м над уровнем моря мы исследовали разные способы применения навоза скота на многолетних травостоях. При первом испытании была установлена более низкая эффективность азота внесенного в навозе скота при эго ежегодном внесении на поверхность или в дерн травостоев на 13 % по сравнению с контрольным вариантом, удобряемом минеральными удобрениями. При поочередном применении (один год навоз, второй год минеральное удобрение) было установлено понижение на 2—3 %. При втором исследовании при внесении навоза в почву в период передпосевной подготовки при быстром обновлении многолетних травостоев в дозах азота 150, 450 кг . га было установлено высоко достоверное повышение продукции сухого вещества на 5,1—10,4 % в среднем пяти лет по сравнению с контрольным вариантом. Проявилось долголетнее действие удобрения навозом, которое благоприятно повышало продукцию сухого вещества в первый год на 5,3 %, на второй год на 12,4 %, на третий год на 15,6 %, на четвертый — на 4,4 % и на пятый на 4,7 %, в среднем доз навоза. При третьем испытании повышение дозы азота поставленной в период подготовки почвы при обновлении (а именно в навозе или в минеральных удобрениях 225 кг . га) вызвало понижение наличие *Trifolium pratense* сорта Кварта в первый продуктивный год на 5,6 % и на другой продуктивный год на 18 %. На понижение наличия *Trifolium pratense* влияли и дозы азота внесенные первый и второй продуктивные годы.

многолетние травостои; навоз скота; питание; быстрое обновление

VAHALA, Z. (Forschungsstation Jevíčko): *Möglichkeiten des Einsatzes von Rindergülle zur Ernährung von Grünland.* Rostl. Výr., *36*, 1990 (5) : 537-546.

In einer klimatischen MT-2-Region auf Auenboden im Rübenanbaugebiet in 340 m Seehöhe testeten wir verschiedene Anwendungsweisen von Rindergülle auf Dauergrünland. Im ersten Versuch wurde eine um 13 % niedrigere Wirksamkeit des in Rindergülle bei ihrer alljährlichen Applikation auf die Oberfläche oder in die Grasnarbe des Grünlands zugeführten Stickstoffs gegenüber der mit Mineraldünger gedüngten Kontrollvariante, festgestellt. Bei Wechselapplikation (ein Jahr Gülle, nächstes Jahr Mineraldünger) wurde eine Verminderung um 2 bis 3 % festgestellt. Im zweiten Versuch, beim Einbringen der Gülle in den Boden zur Zeit der Saatbettbereitung bei einer Schnellerneuerung von Dauergrünland in Stickstoffgaben von 150, 300, 450 kg . ha^{-1} konnte eine hochsignifikante Erhöhung der Trockensubstanzproduktion um 5,1 bis 10,4 % im Durchschnitt von fünf Jahren gegenüber der

Kontrollvariante verzeichnet werden. Dabei kam die langfristige Wirkung der Gülledüngung zum Ausdruck, die die Trockensubstanzproduktion im ersten Jahr um 5,3 %, im zweiten Jahr um 12,4 %, im dritten Jahr um 15,6 %, im vierten Jahr um 4,4 % und im fünften Jahr um 4,7 %, in bezug auf den Durchschnitt der Güllegaben, erhöhte. Im dritten Versuch verursachten erhöhte Stickstoffgaben u. zw. z. Z. der Bodenbearbeitung bei der Erneuerung (in Form von Gülle oder Mineraldünger in einer Höhe von 225 kg . ha^{-1} zugeführt) einen Rückgang der Vertretung von *Trifolium pratense* Sorte Kvarta im ersten Nuntzungsjahr um 5,6 % und im zweiten Nutzungsjahr um 18 %. Auf den Rückgang der Vertretung von *Trifolium pratense* hatten ebenfalls die im ersten und zweiten Nutzungsjahr applizierten Stickstoffdosen ihren Einfluß.

Dauergrünland; Rindergülle; Ernährung; Schnellerneuerung

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THE EFFECTIVENESS OF NO-TILLAGE UNDERPLANTING OF CLOVER CROPS IN GRASSLAND STANDS

Z. Hrazdira

HRAZDIRA, Z. (Research Station Jevíčko): *The effectiveness of no-tillage underplanting of clover crops in grassland stands.* Rostl. Výr., *36,* 1990 (5) : : 547-552.

The effectiveness of underplanting of the thin sown grasslands with tetraploid *Trifolium pratense* L. varieties (Radegast and Kvarta) was demonstrated in the field trials. Through no-tillage technology using the rotary drills in eight subsequent harvests, a similar yield of biomass was produced without mineral nitrogen fertilization as it was in the continuous culture of *Dactylis glomerata* L., annually fertilized at a rate of 240 kg of nitrogen (in pure nutrients) per ha. A possibility of rational utilization of biological fixation of air-borne nitrogen in highly productive grassland communities was demonstrated by the results of the trial.

sown graslands; no-tillage underplanting; effectiveness of biological fixation of nitrogen

An intensification of degraded or low-productivity grasslands by classical technologies of rapid renovation is experimentally worked out and successfully applied in practice if due technological discipline is observed. There is also some negative experience with the used methods of large-scale rapid renovation, especially a decrease of production in the third to fourth years after establishment. The main reason consists in a decline of the less persistent grass components, particularly diploid varieties of clover crops. Thus, the thin grass communities cannot respond effectively even to more intensive fertilization. This results in infestation with weeds, reduction of the production of biomass, decrease in nutritive value along with all other negative consequences.

No-tillage underplanting of thin grass communities was studied not only by foreign authors (Bousman, 1978; Frame et al., 1981; Heichel et al., 1981; Mott, Ernst, 1981; Naylor et al., 1983; Taylor, Allinson, 1983; Vough, Decker, 1983 and others) but also in Czechoslovakia (Holécy, 1975; Hrazdíra, 1984).

The effectiveness of no-tillage underplanting in thin renewed meadow stands with different species of clover crops was the objective of the study.

MATERIALS AND METHODS

Experiments were conducted at a meadow site at an altitude of 330 m above sea level with a total average precipitation of 629 mm (447 mm in the growing alluvial deposits. Groundwater table over 800 mm) has no direct effects on the sod season). The experimental plot was located at an arable site with loamy soils on

I. Experimental treatments

Treatment	Underplanted species	Variety	Under-planting of germinable individuals	Annual fertilization (in kg per ha)		
				N	P	K
1	*Trifolium pratense* L.	Kvarta	7	—	60	60
2	*Trifolium pratense* L.	Radegast	7	—	60	60
3	*Trifolium repens* L.	Huia	5	—	60	60
4	*Trifolium repens* L.	Pastevec	5	—	60	60
5	*Medicago sativa* L.	Pálava	7	—	60	60
6	*Onobrychis sativa* L.	Višňovský	40	—	60	60
7	*Dactylis glomerata* L.	Niva	10	240	60	60

layer. The soil profile down to 550 mm is marked by poor acid soil reaction and medium value of sorption capacity.

The meadow stand renewed five years before the underplanting had the following composition of agrobotanic species: cultivated grasses 65 %, weed species 20 %, and 15 % of empty spots. In the period when the herbage grew for the first cut, the weeds were chemically controlled with the Aniten Combi preparation (4 l per ha). After the first cut, the original grass species 50 to 70 mm tall, were retarded with a 0.05% solution of glyphosate immediatelly followed by no-tillage underplanting with clover crops. Phosphorus and potassium fertilizers were applied in the autumn season, potassium fertilizer was applied before each cut at a rate of 80 kg per ha. The treatments of the trial are given in Tab. I.

The sowing was performed by a no-tillage rotary drill characterized by the fact that separate working sections are swingly mounted so as to copy adequately the unevenness of the soil surface (± 100 mm). This provides an optimum depth of sowing into intact bottom grove, with immediate covering by a layer of 10 to 15 mm of softly cultivated soil (width of grooves 40 mm, depth 25 to 30 mm, row spacing 150 mm). Just before the underplanting, the seed of the clover crops was inoculated with the Rhizobin preparation according to the Czechoslovak Standard ČSN 46 5708.

II. Dry matter yields in t per ha

Treatment	1986			1987		
	cut		S	cut		
	1.	2.		1.	2.	3.
1	4.208	1.350	5.558	6.804	3.647	3.071
2	4.566	1.291	5.857	7.093	3.690	3.211
3	3.650	0.957	4.607	5.810	4.719	2.211
4	3.766	0.843	4.609	5.818	4.279	1.803
5	3.658	1.216	4.874	4.787	4.743	2.323
6	2.657	0.294	2.951	3.493	2.165	0.729
7	3.761	0.226	3.987	5.162	2.930	3.420
$P = 0.05$ t			0.3213			
$P = 0.01$ t			0.4406			

RESULTS AND DISCUSSION

The used technology of underplanting with the rotary drill not only provided rapid sprouting of added seed (undisturbed water capillarity, more intensive utilization of rainfall, condensation of water vapours, lower unproductive evaporation) but also reduced the competitive power of original species which was significant for the development of the plants from the added seed.

The development of added species was intensive, so that two cuts could be performed in the year of underplanting and three cuts in each subsequent year.

It follows from the results (Tab. II) that the highest dry-matter output was recorded in underplanting with *Trifolium pratense,* the Radegast and Kvarta varieties, with no significant difference between them. Other added clover crops produced significantly lower yields of dry matter in comparison with treatments 1 and 2. The lowest yield of dry matter was observed also in the treatment 6 — addition of *Onobrychis sativa,* for which the ecological conditions were not suitable. A highly significantly lower output of dry matter was obtained also in treatments with an addition of *Dactylis glomerata* which, unlike the additionally sown clover crops, were fertilized for each cut with nitrogen fertilizers at a rate of 80 kg per ha.

The highest dry-matter output was also recorded in treatments 1 and 2 in the second harvest year. Neither in that year did the output of *Dactylis glomerata,* underplanted and fertilized with nitrogen reach the output recorded in treatments 1 and 2.

In the third harvest year it was mainly *Trifolium pratense,* the Radegast variety that kept its high production capacity: compared with the Kvarta variety of *Trifolium pratense,* it was highly significantly more productive. Dry-matter output underplanted in *Trifolium repens* treatments was significantly lower than in the preceding year, which can be partly ascribed to damage caused by field vole (*Microtus arvalis*).

	1988				Sum for eight harvests	%
	cut					
S	1.	2.	3.	S		
13.522	3.122	3.811	3.627	10.560	29.640	102.04
13.994	4.014	4.651	3.470	12.135	31.986	110.12
12.740	3.329	4.215	1.037	8.581	25.928	89.28
11.900	3.188	3.053	1.121	7.362	23.871	82.18
11.853	5.463	4.137	2.525	12.125	28.852	99.33
6.387	2.562	2.158	2.199	6.919	16.257	55.97
11.512	4.661	4.888	3.999	13.548	29.047	100.00
0.7833				0.5082		
1.0743				0.6969		

Underplanted *Medicago sativa* had almost the same yield in the third year as the Radegast variety of *Trifolium pratense* which had the highest performance. Underplanted *Dactylis glomerata,* fertilized for each cut with nitrogen at a rate of 80 kg per ha, had the highest dry-matter output in that year.

Apart from other factors, high dry-matter output has a close correlation to the sociological composition. Green matter was analysed agrobotanically from each harvest as weight percentage. Attention was focused mainly on the presence of underplanted species of the clover family (treatments 1 to 6) and *Dactylis glomerata* (treatment 7).

The success of the used technology of underplanting is confirmed by the presence and weight percentage of the added species, recorded already in the herbage of the first cut after underplanting (Tab. III). Except in treatment 5, other clover crops were found to account for as much as 60—70 % by weight. Further spread of *Trifolium pratense,* especially the tetraploid species, was observed in the subsequent harvests, mainly owing to their growing capacity and strong competitive ability. This finding is documented by a total disappearance of *Dactylis glomerata,* which in the original stand of treatments 1 and 2, represented 20 to 25 % of area. *Medicago sativa,* grown at a non-typical meadow site, also suppressed almost completely the grass species.

The addition of *Dactylis glomerata* in treatment 7 provided a perfect establishment of the sod and at the given nitrogen fertilization rates it allowed to form a highly productive continuous culture. The addition of *Onobrychis sativa* was not successful under the given ecological conditions: first of all it produced a low output of biomass and provided a poor stimulation of grass species through biological fixation of air-borne nitrogen. The grass community in treatment 6 was characterized by a low ground layer and by evident signs of deficit in nitrogenous nutrition. This aspect did not change even in the third harvest when *Onobrychis sativa* in the seventh harvest reached as much as 73 % by weight and formed a thin upper layer. On the other hand, in treatments 1 to 5, a deep green colour was observed at all cuts in the original grass species; as the stand was left without nitrogen fertilization, this dark green colour is indicative of a good saturation with rhizobial nitrogen which confirms the results of some authors (Heichel et al., 1981; Kašper, 1984; Máchová, 1988).

In the third harvest year, with the given method of utilization, a considerable decrease of proportions of *Trifolium repens* was found, particularly in the Pastevec variety, with subsequent weed infestation mainly with *Taraxacum officinale* and *Eritrigia repens.*

It can be derived from the presence and production ability of separate clover species that the Kvarta and Radegast varieties of *Trifolium pratense* are suitable for underplanting in meadows stands, the Radegast variety being more productive and more persistent at the given site.

The results of agrobotanical analyses and the presence of separate species and varieties of clover crops can serve for explaining the differences in dry-matter output between treatments left without mineral nitrogen fertilization for eight harvests and treatments of continuous culture of *Dactylis glomerata* fertilized with 80 kg of nitrogen per ha before each harvest.

III. Presence of clover crops in % by weight

Plot	1986		1987			1988		
	cut							
	2.	3.	1.	2.	3.	1.	2.	3.
1	60	61	81	80	97	76	79	71
2	70	83	67	82	88	78	82	85
3	60	71	55	66	71	30	60	20
4	62	76	57	60	61	23	39	3
5	44	81	61	75	95	83	93	99
6	18	24	33	25	40	45	73	58
7	57	23	63	70	90	90	96	95

If treatment 7 is taken as the fertilized control and its dry-matter is 100 %, it becomes evident that this comparatively high output was outyielded by treatments (underplanting with *Trifolium pratense* Kvarta variety by 2.07 %) and treatment 2 (underplanting with *Trifolium pratense* Radegast variety by 10.14 %) which had received no nitrogen fertilizers during eight harvests. The significantly lower dry-matter output of the used varieties of *Trifolium repens* can be largely ascribed to unsuitable harvest frequencies (three cuts).

The results provide evidence of a high effectiveness of the used technology of underplanting in grasslands with no-tillage rotary soil cultivation: in comparison with other methods of underplanting, the tested technology is more effective. Similar results were obtained by Holécy (1975), Mott, Ernst (1981), Hrazdira (1984) and others. An integration of production capacity of the tetraploid varieties of *Trifolium pratense,* which received no nitrogen fertilizer, and fixation of air-borne nitrogen provided similar output of dry matter of above ground biomass as a continuous culture *Dactylis glomerata,* with a nitrogen application rate of 240 kg per ha and year. No-tillage underplanting prolonged the high yield of renovated stands by three harvest years which resulted in return rate of the costs for rapid renovation. Food chain and water cannot be contaminated in the case of absence or reduction of nitrogen fertilization followed by underplanted clover crops. The intensification process has considerably lower energy and personnel inputs.

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HRAZDIRA, Z. (Výzkumná stanice Jevíčko): *Efektivnost bezorebného přísevu jetelovin v lučních porostech.* Rostl. Výr., *36*, 1990 (5) : 547-552.

Polními pokusy byla prokázána efektivnost přísevu prořídlých setých lučních porostů tetraploidními odrůdami *Trifolium pratense* L. (Radegast a Kvarta). Použitou bezorebnou technologií rotačním secím strojem bylo v následujících osmi sklizních dosaženo bez minerálního dusíkatého hnojení obdobné produkce biomasy jako u monokultury *Dactylis glomerata* L., každoročně hnojené dávkou dusíku 240 kg . ha^{-1} v čistých živinách. Výsledky prokazují možnost racionálního využití biologické fixace vzdušného dusíku v lučních vysoce produkčních společenstvech.

seté luční porosty; bezorebný přísev; efektivnost biologické fixace dusíku

ГРАЗДИРА, З. (Научно-исследовательская станция Евичко): **Эффективность безпахотного подсева клеверных и луговых травостоев.** Rostl. Výr., *36*, 1990 (5) : 547-552.

Путем полевых испытаний была доказана эффективность подсева поредевших сеяных луговых травостоев тетраплоидных сортов *Trifolium pratense* L. (Радегаст и Кварта). Применением безпахотной технологии вращающейся сеялки в последующих восьми уборках было получено, без минерального азотного удобрения, аналогичная продукция биомассы, как у монокультуры *Dactylis glomerata* L. ежегодно удобряемая дозой азота 240 кг . га в чистых питательных веществах. Результаты показали возможность рационального использования биологической фиксации воздушного азота в луговых высоко продуктивных обществах.

сеяные луговые травостои; безпахотный подсев; эффективность биологической фиксации азота

HRAZDIRA, Z. (Forschungsstation Jevíčko): *Effektivität der pfluglosen Zusaat von Kleearten in Wiesen.* Rostl. Výr., 36, 1990 (5) : 547-552.

Anhand von Feldversuchen wurde die Effektivität einer Zusaat von Kleearten in ausgedünnte Wiesenbestände u. zw. mit tetraploiden Sorten *Trifolium pratense* L. (Radegast und Kvarta), nachgewiesen. Durch die angewandte pfluglose Technologie der Aussaat mittels Rotationssämaschine wurde in den folgenden acht Ernten ohne mineralische Stickstoffdüngung eine analogische Biomasseproduktion erreicht wie bei der Monokultur *Dactylis glomerata* L., die alljährlich mit einer Stickstoffdosis von 240 kg . ha^{-1} in reinen Nährstoffen gedüngt wurde. Diese Ergebnisse beweisen die Möglichkeit einer rationellen Anwendung der biologischen Fixierung von Luftstickstoff in hochproduktiven Wiesengemeinschaften.

gesäte Wiesenbestände; pfluglose Zusaat; Effektivität der biologischen Stickstofffixierung.

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GRASSLAND UNDERSEEDING AND RENEWAL IN THE WEST BOHEMIAN REGION

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RADĚJ, J. — BUKVAJ, M. — MOLCAR, V. (Research Institute of Crop Production, Praha - Ruzyně): *Grassland underseeding and renewal in the West Bohemian region.* Rostl. Výr., *36,* 1990 (5) : 553-559.

In the grasslands of the former Institute for the Scientific System of Farming, Prague, 82 meadow and pasture plots were underseeded or renewed in 1984 and 1985. The renewal was based on both the use of disk harrow and the ploughing of the sward, followed by cultivation and short-term growing of field crops. The Bettinson drill and the 20 SEXBJ-150 drill, adapted to grass and grass--clover underseeding, were used to add new seeds into the grasslands after the application of the Roundup herbicide. Six mixtures (three of meadow type, three of pasture type) were sown, depending on the soil conditions and methods of exploitation. Nitrogen application rates were differentiated according to the proportions of clovers in the grass stand, according to the yielding potential of the grass mixture, according to the expected length of exploitation, and according to moisture conditions. The herbage yields were higher after the disking of the sward and after traditional tillage. Underseeding without tillage or disking was practiced only under the less favourable soil conditions on hillsides, at sites exposed to the risk of erosion, and in soils that could not be ploughed.

meadows; pastures; grassland; renewal; underseeding; drills; meadow and pasture mixtures; fertilization of grassland

Herbage yields now obtained in the grasslands of the West Bohemian region fail to meet the requirements of advanced livestock production. Some stands have an unsuitable species composition, others are thin and contain a large proportion of weeds. What is lacking most frequently are clovers, particularly white clover. The quality of the herbage harvested from these grasslands is mediocre.

Grassland renewal through disking, arable management for one to two years and subsequent establishment of new grass stands is practiced in areas where the soil is sufficiently fertile and has an adequately thick humus layer, especially at sites not exposed to the risk of erosion. On hillsides, on shallow and stony soils and in zones of hygienic protection of drinking water sources it is better to avoid tillage and to sow the additional seeds directly into uncultivated sward. Herbicides (Roundup or Starane) are applied, the application rates depending on the degree of weed infestation. As there were not enough comparable data on different underseeding methods, pilot experiments were conducted to study both traditional methods of renewal and no-tillage underseeding.

One of the reasons why the pilot experiments were conducted was the intention to verify the results of the general investigation conducted by the members of the Central Commission for Fodder Base of the Czechoslovak Academy of Agriculture (Benda, 1982). The suitable machines and implements used in Hungary, the basic principles and the results of similar experiments were described by Hajdú (1982).

MATERIALS AND METHODS

Grassland was renovated both by means of disk harrows and by ploughing up the sward, followed by cultivation with a short period of field crop growing, as described by Haken et al. (1981, 1986). Underseeding without tillage was practiced on the basis of recommendations published by Bukvaj et al. (1987), Raděj (1983), Hajdú (1982), Squires et al. (1979), Stewart (1981), and Charles (1982). Two drills were used: the Bettinsson dril (from Great Britain) and the 20 SEXBJ-150 drill (slotseeder type), adapted for grass and clover underseeding. The pilot trials were performed on the Domažlice State Farm, Draženov Co-operative Farm, Úněšov State Farm and Zbiroh Co-operative Farm, located 450 to 700 m above sea level, on shallow and stony soils on hillsides, with different intensities of weed infestation (*Rumex* ssp., *Polygonum* ssp., *Geranium* ssp., *Ranunculus acer*, *Taraxacum officinale*, *Deschampsia caespitosa* and others). The average annual precipitation at the experimental sites ranged between 620 and 700 mm, the soil pH was 5.1 to 6.0, the thickness of the humus layer was 10 to 18 cm. Before the renewal, the yields ranged

I. Composition of pasture and meadow mixtures

Species — varieties	Sowing rate in kg per 1 ha					
	pasture mixture			meadow mixture		
	1	2	3	4	5	6
Dactylis glomerata — Milona	15			12	4	
Phleum pratense — Levočský	3	8	8			
Festuca pratensis — Otava	4	10	6	4	8	5
Lolium perenne — Tarpan	3			3		
Trifolium repens — Huia	3	3	4	2	3	3
Lolium perenne — Bača		5				
Festuca rubra — Táborská		4	6		3	
Poa pratensis — Monopoly		4	3			3
Trisetum flavescens — Větrovský			3			
Agrostis alba — Levočský			2			2
Lolium hybridum — Odra				3		
Trifolium pratense — Kvarta				6	2	
Phleum pratense — Větrovský					8	6
Arrhenatherum elatius — Levočský					6	
Alopecurus pratensis — Levočská						5
Phalaris arundinacea						8
Trifolium hybridum — Táborský						4
Total	28	34	32	30	34	36

from 4.5 to 6 t of dry mateer per ha, the grassland being fertilized at rates of 120 to 150 NPK per ha (depending on yield potential).

The underseeding was always performed after the first cut (grazing) between June 10 and August 15. The Roundup herbicide was applied at a rate of 4 to 6 litres per 1 ha into regenerated sward (grass height 10 to 15 cm). The no-tillage underseeding itself was performed three weeks after the application of Rounddup (and harvest of the killed herbage). In that period the herbicidal action still slightly persisted and the sward was totally killed.

Three types of pasture mixture and three meadow mixtures were sown. Their composition is shown in Tab. I.

Pasture mixture 1 was designed for deeper soils; it is an early mixture, the renewal being planned after four to six years. Mixture 2 was medium-late to late, with planned renewal after six to eight years. Mixture 3 was intended for extreme and stony soils and the stand was planned to be renewed after eight to ten years. Mixture 4 was early and was sown in temporary meadows to be renewed after three to four years. Mixture 5 was prepared for the submontane areas and was to persist for five to six years. Mixture 6 was designed for damp sites where they were to remain productive for eight to ten years.

The pasture and meadow mixtures were prepared on the basis of recommendations of the Central Commission for Fodder Base of the Czechoslovak Academy of Agriculture. They were prepared at the Rožnov pod Radhoštěm seed cleaning plant of the Oseva Corporation. For each site, the mixtures were chosen with respect to altitude, soil conditions, thickness of the humus profile, ground water table, yield potential of the site, method of grassland exploitation, exposition of the site, and weed infestation.

The grassland was exploited by cutting and grazing. The first cuts were mostly used for the production of hay or wilted silage. The yields of green herbage, wilted silage and hay were converted to dry matter data.

Commercial fertilizers were aplied by stages (before establishment of the stand, during regeneration and after harvest). Phosphorus application rates were determined according to the results of agrochemical soil testing. Nitrogen fertilizer rate were determined on the basis of the proportions of clovers, yield potential of the mixture, length of exploitation of the grassland, moisture conditions, and year season. The nitrogen fertilization rates are shown in Tab. II.

RESULTS

The year 1986 brought sufficient moisture and the herbage increment was much greater than in 1987. The higher yields obtained in the soils that could be ploughed can be partly ascribed to the effect of better soil conditions and better nutrient reserve. In plots underseeded without tillage, a higher effect was exerted on the yields by favourable weather, in comparison with the yields obtained in grasslands established in the traditional way. Successful development of grasslands established without tillage (without companion crop) also depended on timely cut of the

II. Nitrogen fertilization in kg per 1 ha

Harvest year	Proportion of clovers		
	low*	medium**	high***
1	120	60	40
2	140	80	60
3	160	100	80

* – clovers up to 10 % ** – 11 to 30 % *** – over 30 %

III. Dry matter yields in t per 1 ha

Year	1986		1987	
Mixture	renovation by tillage	no-tillage overseeding	renovation by tillage	no-tillage overseeding
		in pasture		
1	12.7	9.2	7.6	7.4
2	10.7	9.6	8.6	7.5
3	10.4	8.1	9.1	7.1
		in meadow		
4	10.5	8.1	8.5	6.8
5	10.6	8.0	8.4	6.6
6	8.6	7.2	8.1	6.7
Average	10.53	8.37	8.38	7.02

first amount of herbage produced in the sowing year, as reported by Boatman, Haggar (1985). Dry matter yields obtained in both years are given in Tab. III.

The highest dry matter yield was recorded in treatments where disk harrows or tillage were used for the renewal. In this method, mixture no. 1 with a prevalence of *Dactylis glomerata* proved to be the best. The remaining mixtures (except mixture no. 6) had about the same yields. In the no-tillage system of renewal, pasture mixture no. 2 (major grass: *Festuca pratensis*) was the best in the first year of exploitation. It should be noted that in the subsequent years there were only small differences between the mixtures sown. Larger differences were due to the effect of the site and to the method of sowing. Underseeding without tillage was practiced in really poor soil conditions (shallow soils, hillside soils, skeletal soils). On the other hand, renewal with traditional soil cultivation was performed on soils with a higher yield potential.

The proportions of clovers in the grass stands varied greatly. This was due not only to the competition relationships or to the effect of nitrogen fertilization, but mainly to the soil conditions. For example, a stand in which white clover preailed was established with success in the grasslands of the Úterý centre of the Úněšov State Farm. The causes will be investigated in further experiments.

DISCUSSION

The pilot experiments have demonstrated the possibility of using new methods of improving grassland management by underseeding into uncultivated sward. However, as distinct from the traditional method of sowing and soil cultivation, the optimum composition of the grass mixtures is not so effective under worse soil conditions (i. e. on soils with a poor yield potential). It should be mentioned, on the other hand, that the described method of permanent grassland improvement is well applicable to the grasslands located at sites that cannot be ploughed, i. e. on soils where the humus layer contains a large proportion of stones whose removal is costly and whose presence causes serious damage to the harvest machines. At such sites, dry matter yields about 6.5 t per 1 ha, obtained with minimum costs of fertilization, should be regarded as sufficient.

Weed control with the Roundup herbicide is successful at sites where the weed infestation is not very high. This is in keeping with views published by Meurk, Turner (1985), Willocks, Desborough (1985), and Curll, Gleeson (1987). Where there is a larger proportion of *Rumex obtusifolius* in the stand, it is better to use a point control method rather than to increase the amount of the costly Roundup applied per 1 ha. The thicker the root or this weed the worse the control.

The Bettinson drill worked better in the uneven terrain than did the 20 SEXBJ-150 drill. However, neither of them was able to place the seeds of *Poa pratensis* in the desirable depth. The stands that grew from the seed drilled in the latter half of June and early in July were denser and contained more clover than those sown later, in August. The same observation was published by Williams, Hayer (1987), concerning the Huia variety of white clover.

Sowing without tillage has the following advantages:

— disturbance of the sward is reduced; this in turn reduces the danger of erosion,
— labour costs and fuel requirement are low,
— the "dropout" in forage production is reduced,
— there is no other method, safe for the environment, of grassland improvement at sites where tillage is impossible.

Under the conditions of the West Bohemian region, the costs per 1 ha of renovated grassland ranged between 4700 and 5650 crowns. The price of Roundup, including aplication (2140 crowns if the herbicide is applied at a rate of 6 litres per ha) should be added to this sum. It is suggested by the results obtained until now that the non-investment costs of the renovation of grasslands will pay back in two years and a half up to three years.

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RADĚJ, J. — BUKVAJ, M. — MOLCAR, V. (Výzkumný ústav rostlinné výroby, Praha - Ruzyně): ***Přísevy a obnovy luk a pastvin v Západočeském kraji.*** Rostl. Výr., *36*, 1990 (5) : 553-559.

V letech 1984 a 1985 bylo přiseto nebo obnoveno na pracoších bývalého ÚVSH Praha 82 lokalit luk a pastvin. Obnova byla realizována jak diskovými branami, tak i zaoráním drnu, následným rozpracováním s krátkým pěstováním polních plodin. Přísevy do drnu se uskutečnily pomocí secího stroje značky Bettinson a secího stroje 20 SEXBJ-150 upraveným pro přísev trav a jetelovin po aplikaci herbicidu Roundup. Podle půdních podmínek a způsobu využívání bylo vyseto šest směsí (tři luční a tři pastevní). Hnojení dusíkem bylo diferencováno podle podílu jetelovin v travním porostu, podle výnosového potenciálu travní směsi, podle předpokládané délky využívání porostu a podle vláhových podmínek. Výnosy píce byly vyšší po rozdiskování drnu a po tradiční orbě. Bezorebné přísevy byly realizovány v horších půdních podmínkách na svazích, v erozně ohrožených lokalitách a na neoratelných půdách.

louky; pastviny; travní porosty; obnovy; přísevy; secí stroje; luční a pastevní směsi; hnojení; exploatace travních porostů

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В 1984—1985 гг. был сделан подсев или проведено обновление на рабочих местах бывшего НИВСГ Прага 82 местонахождений лугов и пастбищ. Обновление было проведено как дисковыми боронами, так и запаханым дерном, последующей разработкой с кратким выращиванием полевых культур. Подсевы в дерн были проведены при помощи сеялки марки Бетинсон и сеялки 20 СЕКСБЙ-150 подготовленной для подсева трав и клеверных после применения гербицида Роундуп. Согласно почвенным условиям и способу использования было посеяно шесть смесей (три луговых и три пастбищных). Удобрение азотом дифференцировали согласно доле клеверных в травостое, согласно урожайному потенциалу травосмеси, согласно предполагаемой продолжительность использования травостоя и согласно условиям влажности. Урожаи зеленого корма были выше после обработки дерна диском и после традиционной пахоты. Безпахотные подсевы проводились в более плохих почвенных условиях на склонах, в местах, которым угрожает эрозия и на поддающихся пахоте почвах.

луга; пастбища; травостои; обновления; подсевы; сеялки; луговые и пастбищные смеси; удобрение; эксплуатация травостоев

RADĚJ, J. — BUKVAJ, M. — MOLCAR, V. (Forschungsinstitut für Pflanzenproduktion, Praha - Ruzyně): *Beisaaten und Erneuerungen von Wiesen und Weiden im Bezirk Westböhmen.* Rostl. Výr., *36*, 1990 (5) : 553-559.

In den Jahren 1984 und 1985 wurden an den Arbeitsstätten des ehemaligen Instituts für wissenschaftliche Wirtschaftssysteme Prag 82 Wiesen- und Weidenlokalitäten durch Beisaat oder Erneuerung bearbeitet. Die Erneuerung wurde sowohl mittels Scheibeneggen als auch durch Wenden der Grasnarbe, mit nachfolgender Bearbeitung mit kurzfristigem Anbau von Feldfrüchten, realisiert. Die Beisaaten in die Narbe wurden mittels Sämaschinen vom Typ Bettinson und der Sämaschine 20 SEXBJ-150, die zur Beisaat von Gräsern und Kleearten nach Applikation des Herbizids Roundup modifiziert waren, vorgenommen. Den Bodenbedingungen und der Nutzungsweise nach wurden sechs Gemische (drei Wiesen- und drei Weidegemische) ausgesät. Die Stickstoffdüngung wurde dem Anteil der Kleearten im Gräserbestand, dem Ertragspotential der Grasmischung, der vorausgesetzten Nutzungsdauer und den Niederschlagsbedingungen nach, differenziert. Die Futtererträge waren höher nach der Eggenbearbeitung der Grasnarbe und nach traditionellem Pflügen. Die pfluglosen Beissaaten wurden in schlechteren Bodenbedingungen in Hanglagen, auf erosionsbedrohten Lagen und auf nichtpflügbaren Böden realisiert.

Wiesen; Weiden; Gräserbestände, Erneuerung; Beisaaten; Sämaschinen; Wiesen- und Weidegemische; Düngung; Exploitation der Gräserbestände

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REVIEW

GRASS SEED PRODUCTION

B. Cagaš, J. Macháč, P. Šrámek, J. Folta, V. Tvrz

Praha, SEVT 1989, 150 pp.

More than 10 years after publication of the J. Demel's — *Cross Seed Production*, a thematically similar book is now published, written by a collective of young but experienced specialists, who continue with enthusiasm in the Rožnov grass cultivation traditions. The book is written in a modern way, in a comprehensive and well-arranged form, and contains an extensive amount of carefully selected useful information, research findings and recent methods well-tested in practice, emphasizing their actual utilization on seed production farms.

In the separate chapters, the basic data and characteristics of the present Czechoslovak certified varieties and promising newly developed interspecific hybrids are given, and there are characterized the principles of grass cultivation for seed. Attention is also drawn to the special requirements of species, to protection against dangerous diseases and pests, to harvest and post-harvest seed treatment, and to the economy of seed grass production.

25 pen-and-ink drawings and drawings, 12 diagrams, 65 nice photographs and 30 tables are included suitably in the text. The book bears the impress a high qualification and expertise of the authors but it is also attractive from the formal point of view. It will certainly become a much demanded guide for specialists in the given field as well as for broader agricultural public outside the close circle of narrow specialists.

Ing. Václav Míka, DrSc.

СОДЕРЖАНИЕ — Травостои

INHALT — Grasbestände

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