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REPRESENTATION OF PLANT SPECIES IN THE STAND IN DEPENDENCE ON TOTAL PRECIPITATION AMOUNTS, TEMPERATURE, INTENSITY OF FERTILIZATION AND USE IN THE PERIOD 2007-2011

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Abstract

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Grasslands in central Europe came to existence as communities substitute to forests and fulfill both the production function and other beneficial functions for the society. For the due fulfillment of these functions, the grass stands have to be managed so that their biodiversity as well as quality and high yields can be maintained. The objective of our work was to compare changes in the representation of plant species in dependence on total precipitation amounts, temperature, fertilization intensity and intensity of use in the period 2007-2011.

Characteristics assessed included dry matter yields, proportions of individual agro-botanical groups, Shannon's diversity index and grass stand quality. It was demonstrated that high supply of nutrients shows in the increased ($P<0.05$) representation of *Alopecurus pratensis* whose share increased from 6.3% to 36.4% after the application of 180 kg N. Its proportion however depended on total precipitation amounts, too. In the years 2007 and 2009 when the precipitation in the month of April was markedly below the long-term average, the species' share was the lowest. Increased shares of Festuca rubra and *Poa* spp. compensated the decreased representation of Alopecurus pratensis. The proportion of *Trifolium repens* was also depending on the year ($P<0.05$). Higher average temperatures in the spring months (2007) reflected positively in its representation (4.8%). By contrast, its representation was only 0.9% in 2010 when the temperatures were the lowest. High doses of nutrients showed to be beneficial also for the quality and yield of grass stands. Fertilization had an adverse effect on the biological diversity, which was decreasing with the increasing dosing of fertilizers. Higher intensity of exploitation appeared to be appropriate measure to support biodiversity.

Key words: biodiversity, nitrogen, phosphorus, potassium, number of cuts, primary production

Introduction

Grasslands are the most abundant cover of our planet right after forests. In the Czech territory, they came into existence as communities substitute to forests and play a non-substitutable role in the nutrition of farm animals today. Besides the primary functions of production, they fulfill a range of other beneficial functions, too, which are no less important for the society. A multi-functional harmonious landscape formed by grasslands provides economic benefits as well as ecological and social functions such as protection of biodiversity, soils and air (Kampmann et al., 2011). The other beneficial functions depend primarily on the preservation of biodiversity. At present, many parts of central Europe show a significant decrease of species-rich grasslands caused either by land use intensification or by neglected management (Schmiede et al., 2012).

As heterogeneous associations, grasslands feature considerable species diversity, which reflects in phytomass quality (Mrkvička and Veselá, 2002). Decisive for yields and forage quality is floristic composition, which is given by site, fertilization and management methods (Fiala et al., 2007). Species composition can be influenced by thoughtful measures so that both species diversity and forage quality can be preserved at economical inputs (Gaisler et al., 1998). On the

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other hand, inadequate management methods such as excessive fertilization and high frequency of use may result in the degradation of grasslands in terms of their species composition (Chapman, 2001). Superfluous fertilization may result even in negative succession and related decreased production of aboveground biomass (Hanze et al., 2004). Both agronomists and environmentalists (Garnier et al., 1997) have tackled question whether the productivity of plant communities really depends on the species abundance.

The objective of this work was to compare changes in the individual species representation of a grass stand of *Sanguisorba-Festucetum comutatae* association in dependence on total precipitation amounts, temperature, intensity of fertilization and frequency of use in the period 2007-2011. Another goal was to ascertain how a high supply of nutrients reflects in the species composition of the grass stand, forage quality and yield, and to suggest an optimum method of use that would maintain an optimum between the species diversity and grass stand quality.

Material and Methods

Experimental site characteristics

Our experimental plot was established in the cadastre of the village Kameničky belonging in the Protected Landscape Area (PLA) of Žďárské vrchy Hills. Experimental works were launched there in 1992. The presented results include the years from 2007-2011. The site has a SW aspect and is situated on a slope with the gradient of 3%. Mean annual temperature (1951-2000) is 5.8°C and mean total annual precipitation amounts to 758.4 mm. Soil type is acidic Luvic Stagnosol on the gneiss diluvium. Soil is loamy sand to loam. The contents of available nutrients established by the Mehlich III method are presented in Table 1.

Layout of the experiment

The experiment was laid out by using the method of split compartments in four repetitions. Each plot is sized 15 m^2 (1.5m×10m). We studied two factors. The first factor was fertilization (no fertilization, PK fertilization, N90+PK fertilization and N180+PK fertilization. The second studied factor was the intensity of exploitation (2 cuts and 3 cuts).

Treatment of the experimental site

Nitrogen was supplied in the form of ammonium nitrate with limestone (LAV 27%) at a total dose of 90 $kg.ha^{-1}$ N, resp. 180 $kg.ha^{-1}$ N. In the mode of three cuts, the dose of nitrogen was applied in three terms (1/3 in spring, 1/3 after 1st cut and 1/3 after 2nd cut). In the mode of two cuts, the dose was applied in two terms (2/3 in spring and 1/3 after 1st cut). Potassic and phosphoric fertilizers were applied in spring. Phosphorus was applied in the form of Hyperkorn (26%) at 30 $kg.ha^{-1}$ P and potassium was applied in the form of potassium salt (60%) at 60 $kg.ha^{-1}$ K. In the mode of three cuts, the stands were harvested at three terms (early June, early August and early October) and in the mode of two cuts, they were harvested at two terms (mid-June and early September). The grass was harvested by the mower Model MF-70 with a cutting bar with engagement of 1.2 m. The harvested area was 12 m^2 and the stubble height was 0.07 m.

Assessed characteristics

Characteristics assessed in our experiment included dry matter yields in the respective cuts, the share of individual agro-botanical groups in the 1st cut forage, Shannon's diversity index (H), and grass stand quality ascertained according to the feeding value of individual species (EGQ). In order to establish the share of individual species or agro-botanical groups in the harvested forage, samples were taken of aboveground biomass from permanently staked plots (0.5 m^2). The samples of aboveground forage biomass were divided into individual species and dried at 60°C. Subsequently, their weight was ascertained in dry state and the proportions of individual species were expressed as percentages from the total weight of dry forage. Total precipitation amounts and average temperatures in individual months were obtained from the CHMI meteorological station in Svratouch. The acquired data are presented in diagrams (Figures 1, 2, 3 and 4) and climadiagrams (Figures 5, 6, 7, 8, 9 and 10).

$$H = -\sum P_i \ln P_i ,$$

where H is diversity index and P_i is the share of the i^{th} species in the stand.

Table 1
Soil contents of available nutrients [$mg.kg^{-1}$]

Fertilizer intensity	P	K	Ca	Mg	pH
No fertilizer	13.4	51.4	1253	94.3	4.2
PK	22.6	50.9	1440	90.9	4.4
N 90 + PK	31.6	55.9	1333.3	92.6	4.3
N 180 + PK	36.1	52.8	1386.7	79.1	4.4

Grass stand quality (Novák, 2004) was calculated according to the below formula:

$E_{GQ} = \sum(D*FV)/8$,

where E_{GQ} is grass stand classification, D is the species proportion (%) in the harvested forage and FV is feeding value of the given species. Each plant species has its own feeding value on the scale of 13 points (from -4 to 8). Highly valuable species are classified with 8 and highly poisonous species are classified with -4.

Statistical evaluation

Statistical evaluation was conducted with using the Statistica 6.0 CZ programme. The effect of fertilization on the yields of dry forage and the proportion of individual species in the stand were assessed by multi-factorial analysis of variance (ANOVA) and by Tukey test.

Results and Discussion

Representation of grasses in the stand

The agro-botanical group with the highest percentage share in the studied period of five years consisted of grasses with 57.4% and 52.4% in the 2-cut and 3-cut stand variants. As compared with the unfertilized variant and the variant with additional PK, the fertilization with nitrogen had a statistically significant influence (P<0.05) on the increasing representation of grasses in the stand. Camská and Skálová (2012) reported the same finding, too. The proportion of grasses in the stand was also influenced by the order of the cut with their percentage share increasing with the increasing order of the cut. On the other hand, the representation of grasses at 3-cut use was lower than at 2-cut use when the date of the first cut was delayed. Kramberger et al. (2005) arrived at the same conclusion that a later date of the first cut increases the proportion of grasses in the stand. In the 2-cut variant, a statistically significant difference (P<0.05) was demonstrated in the percentage representation of grasses between the first (54.5%) and second (60.3%) cuts. In the 3-cut variants, a statistically significant difference (P<0.05) was found between the second (50.5%) and third (61.1%) cuts. The results are presented in Table 2. The high percentage share of grasses was most contributed to by *Alopecurus pratensis*, which dominated, and by *Festuca rubra* and *Poa* spp., which occurred in abundance, too. *Phleum pratense*, *Antoxanthum odoratum* and other grass species occurred at much lower percentage shares. The results (Table 3) indicate that fertilization had a significant influence (P<0.05) on the dominance of *Alopecurus pratensis* in the stand. While the species occupied only 6.3% in the unfertilized variant, its representation increased to 21.6% in the variant with the PK fertilization and even to 41.1% in the variant fertilized with N90+PK. The positive influence of N-fertilization on the increased proportion of *Alopecurus pratensis* was demonstrated also by Smith et al. (1996), Gaisler et al. (1998) and Mrkvička and Veselá (2002). The proportion of *Alopecurus pratensis* in the stand was also affected by the year, i.e. by average temperatures and total precipitation amounts in individual months (Table 3, Figure 1). The lowest share of *Alopecurus pratensis* in the stand was detected in 2007 (17.3%) when the total precipitation in the month of April amounted only to 5.58mm (Figure 5). The waning of *Alopecurus pratensis* was compensated for by the increased shares of *Poa* spp. and namely *Festuca rubra* whose representation was the highest in the studied 5-year period (Table 3). These species are of low build and the smaller proportion of *Alopecurus pratensis* made it possible for them to win more ground in the stand. Moreover, the resistance of *Festuca rubra* to the lack of rainfall is well known (Ruemele et al., 1995; Bandurska et al., 2010). A lower representation of *Alopecurus pratensis* (26.1%) was recorded also in the year 2009 when the total precipitation amount in the month of April was very low too – only 7.37 mm (Fig-

Table 2
Shares [%] of agro-botanical groups in the individual experimental variants in the period 2007-2011

2-cut	Grasses	Herb species	Clover crops	3-cut	Grasses	Herb species	Clover crops
No fertilizer	36.9^{a}	60.6^{a}	1.9^{a}	No fertilizer	45.9^{a}	52.0^{a}	2.1^{a}
PK	44.6^{a}	45.9^{b}	9.5^{b}	PK	38.7^{a}	47.2^{a}	14.1^{c}
90N+PK	74.2^{b}	25.0^{c}	0.8^{a}	90N	61.4^{b}	31.7^{b}	6.9^{b}
180N+PK	74.0^{b}	26.0^{c}	0.0^{a}	180N	63.7^{b}	35.6^{b}	0.7^{a}
1st cut	54.5^{a}	42.6^{a}	2.9^{a}	1st cut	45.7^{a}	49.5^{a}	4.9^{a}
2nd cut	60.3^{b}	36.1^{b}	3.3^{a}	2nd cut	50.5^{a}	41.5^{b}	7.9^{b}
Mean	57.4^{a}	6.5^{b}	35.9^{c}	3rd cut	61.1^{b}	33.9^{c}	5.0^{ab}
				Mean	52.4^{a}	8.6^{b}	39.0^{c}

Average values in the same columns with different upper indices are statistically significant at a level of P<0.05

ure 7). On the other hand, in 2011 when total precipitation amounts were evenly distributed over the spring period (Figure 9), the representation of *Alopecurus pratensis* was the highest (31.4%) and exhibited a statistically significant difference ($P<0.05$) when compared with the year 2007 (Figure 5). Other authors (Lapinshiene, 1998; Gotze et al., 2010) mention the dominance of Alopecurus pratensis especially on humid sites also. The shares of *Poa* spp. and *Festuca rubra* were decreasing proportionally with the increasing share of *Alopecurus pratensis*, being the lowest in this year (2011) in the studied 5-year period (Table 3). The ascertained results suggest that *Alopecurus pratensis* reacts very sensitively to the lack of precipitation in spring by decreasing its share namely in the month of April when it shows an intensive overgrowth. A fact supporting this statement is that this very early species has a shallow root system. By contrast, the species that overgrow intensively later (*Festuca rubra*, *Poa* spp.) were capable to respond to rainfall as late as May and to establish themselves against *Alopecurus pratensis*.

It might seem based on the above facts that the share of *Poa* spp. increases in dry years but the statement would be misleading because it is necessary to take into account not only the total precipitation amounts in April but also the whole spring period. A statistically significant difference ($P<0.05$) was found between the representation of *Poa* spp. in 2010 (7.5%) and in 2011 (3.9%). The explanation appears to be total precipitation amounts the sum of which in 2010 (January-May) was 360.12 mm while in 2011 they dropped to not even a half – 163.03 mm (Figure 2). The fact consequently showed in the percentage share of *Poa* spp. The results suggest that total precipitation amount in spring months is an important factor for *Poa* spp.

Table 3
Shares of dominant grass and clover species in dependence on fertilization and intensity of exploitation in the first cut (2007-2011)

Factor	Phleum pratense	Festuca rubra	Poa ssp.	Alopecurus pratensis	Antoxanthum odoratum	Lathyrus pratensis	Trifolium repens
No fertilizer	1.3^{a}	10.4^{a}	1.9^{a}	6.3^{a}	6.1^{a}	0.2^{a}	0.8^{a}
PK	2.9^{ab}	3.5^{b}	4.2^{ab}	21.6^{b}	3.6^{ab}	2.6^{b}	6.6^{b}
90N+PK	5.2^{b}	1.6^{b}	6.2^{b}	41.1^{c}	2.0^{bc}	0.0^{a}	3.5^{ab}
180N+PK	0.9^{a}	3.5^{b}	11.9^{c}	36.4^{c}	0.3^{c}	0.0^{a}	0.4^{a}
2007	2.8	8.9	6.9^{ab}	17.3^{a}	2.5	0	4.8^{a}
2008	2.2	4.4	5.4^{ab}	29.6^{ab}	4.3	1.2	3.4^{ab}
2009	4.2	3.7	6.4^{ab}	26.1^{ab}	3.6	0.9	1.8^{ab}
2010	2.5	3.6	7.5^{b}	27.3^{ab}	3.4	1	0.9^{b}
2011	1.1	3.1	3.9^{a}	31.4^{b}	1.2	0.4	3.3^{ab}
2-cut	3.4	2.8^{a}	5.1^{a}	31.8^{a}	3.7	1.2	1.3^{a}
3-cut	1.8	6.7^{b}	7.0^{b}	20.8^{b}	2.3	0.2	4.3^{b}

Average values in the same columns with different upper indices are statistically significant at a level of $P<0.05$

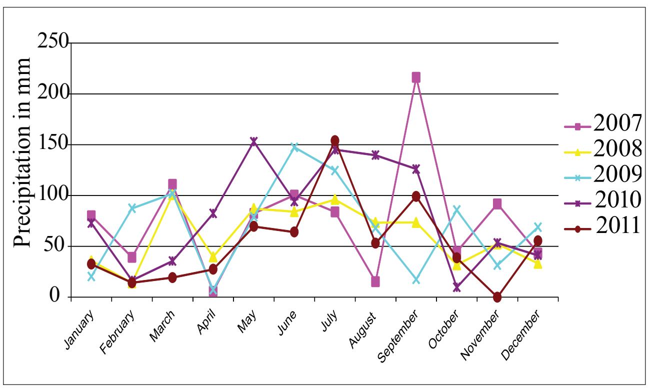

Fig. 1. Average precipitation in the individual months of years 2007-2011

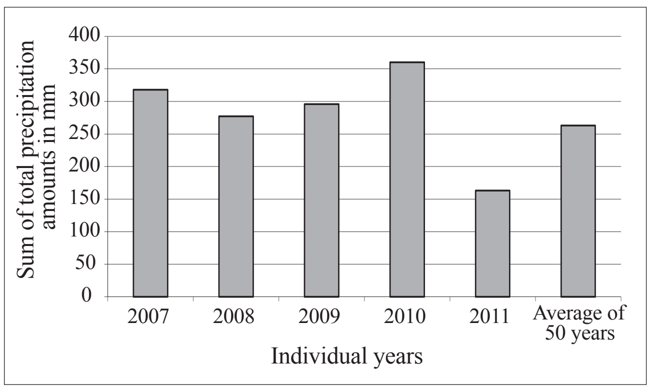

Fig. 2. Sum of average total precipitation amounts in the first five months of individual years

A similar trend as *Alopecurus pratensis* with N-fertilization was shown also by *Phleum pratense* and *Poa* spp. in which a statistically significant difference (P<0.05) was found between the percentage representation in the unfertilized variant and in the variant with N90+PK (Table 3). Busey (2003) demonstrated the increased representation of both species with nitrogen fertilizers, too. The two species exhibited a statistically significant (P<0.05) difference also between the variant with N90+PK (6.2%) and the N180+PK variant (11.9%). However, the percentage share of *Poa* spp. increased with the increasing nitrogen supply from 6.2% in the variant with N90+PK to 11.9% in the variant with

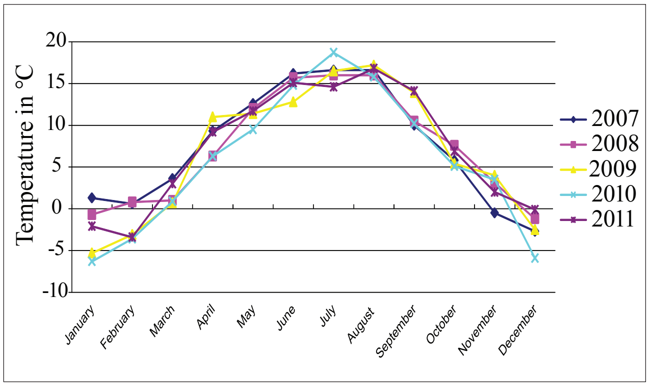

Fig. 3. Average temperatures in the individual months of years 2007-2011

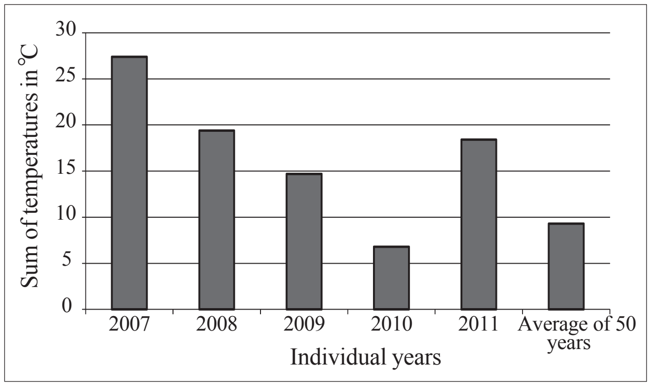

Fig. 4. Sum of average temperatures in the first five months of individual years

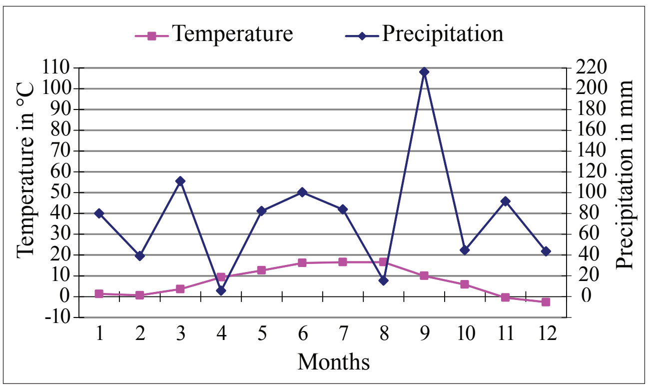

Fig. 5. Climadiagram 2007

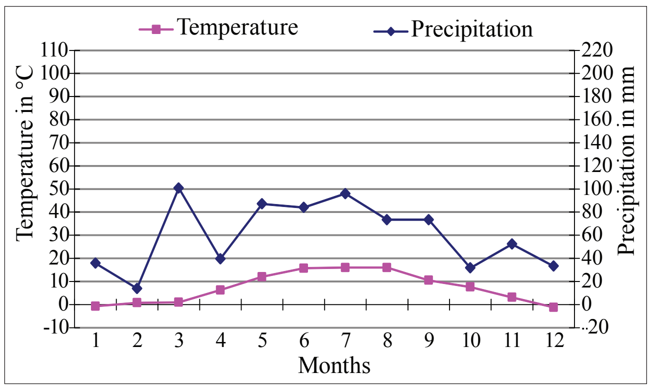

Fig. 6. Climadiagram 2008

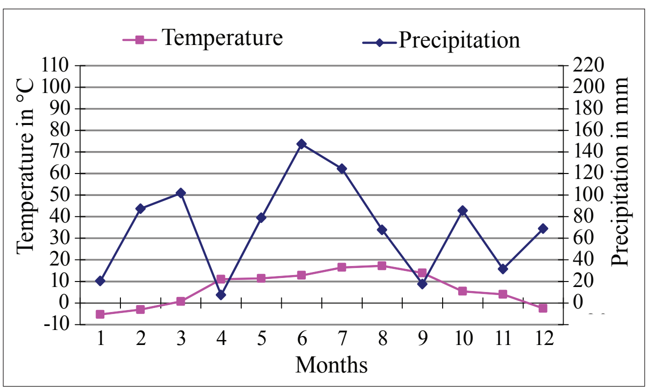

Fig. 7. Climadiagram 2009

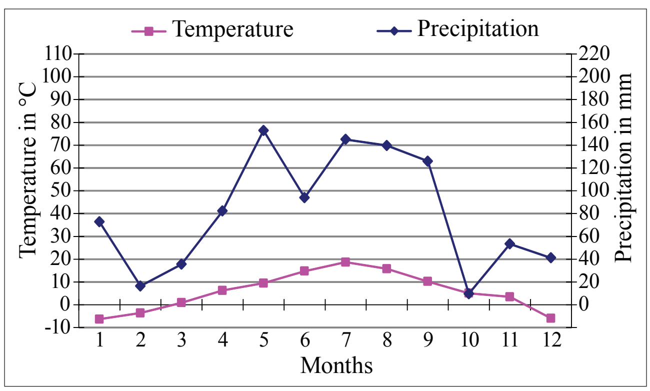

Fig. 8. Climadiagram 2010

N180+PK while in *Phleum pratense* it was decreasing from 5.2% to 0.9%, probably due to the heavy competition of other species. *Alopecurus pratensis* showed a similarly decreasing trend between the variants N90+PK (41.1%) and N180+PK (36.4%); however, the difference was not statistically significant. *Antoxynthum odoratum* and *Festuca rubra* exhibited an opposite trend (Table 3); unlike in the above species, their representation was decreasing with the increasing supply of nutrients, probably due to the severe competitive capacity of tall grasses, which can better use doping with nitrogen for their growth and thus suppress the lower grass species such as *Antoxanthum odoratum* and *Festura rubra*. The greatest difference was recorded in *Antoxanthum odoratum*, in which statistical differences between the unfertilized variant (6.1%) and the variant fertilized with N90+PK (2%), and between the variant with additional PK (3.6%) and the variant with N180+PK (0.3%) were significant ($P<0.05$). In *Festuca rubra*, a statistically significant difference ($P<0.05$) was found between the unfertilized variant and the PK variant when its representation decreased from 10.4% to 3.5%. The species forms a more branched root system under wanting nitrogen rather than under its surplus; however, this competitive advantage fades away with a higher nitrogen supply (Gastal et al., 2010). As compared with fertilized stands, the higher proportion of *Festuca rubra* in unfertilized stands, which wins ground in them at the expense of *Alopecurus pratensis* was confirmed also by Mrkvička and Veselá (1997) and Hejcman et al. (2012). Differences were also in the representation of the respective species between the 2-cut and 3-cut use of the stand (Table 3). While the share of the high-growing *Alopecurus pratensis* exhibited a statistically significant decrease ($P<0.05$) at higher intensity of use from 31.8% to 20.8%, the species of lower built *Festuca rubra* could make advantage of the fact in the stand and increased its share from 2.8% to

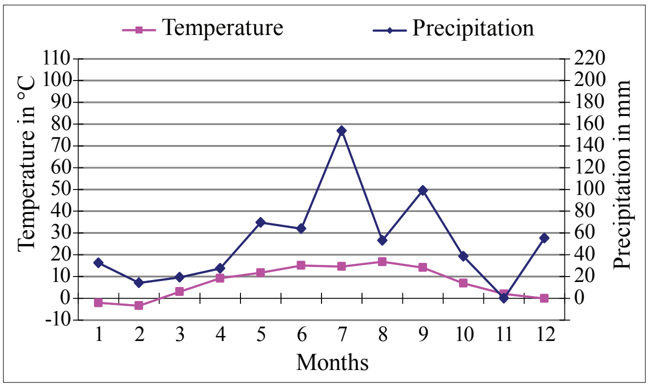

Fig. 9. Climadiagram 2011

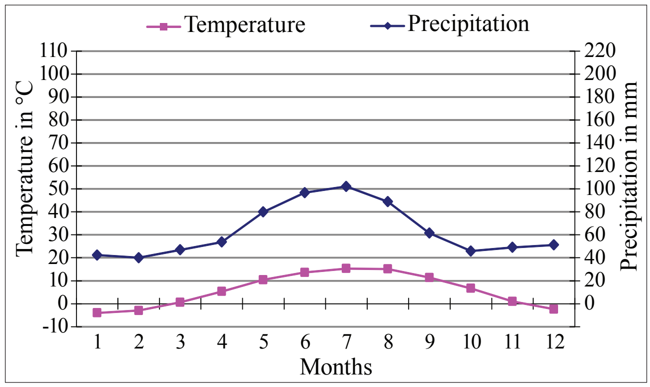

Fig. 10. Climadiagram 50-year average

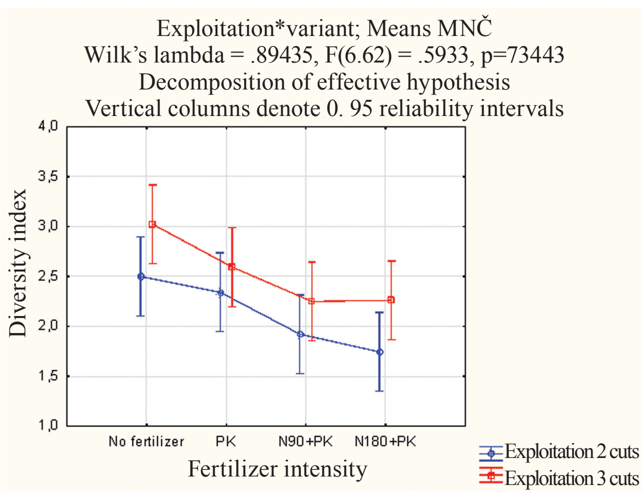

Fig. 11. Diversity of grass stands in dependence on fertilization and intensity of exploitation

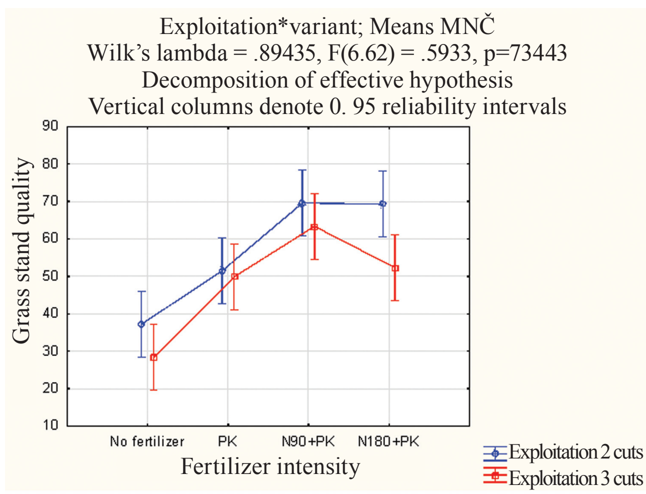

Fig. 12. Quality of grass stands in dependence on fertilization and intensity of exploitation

6.7%. The representation of *Phleum pratense* in the stand was also dependent on the intensity of use with 3.4% in the 2-cut stand and 1.8% in the 3-cut stand. This finding corresponds with results reported by Nissinen et al. (1995) who recorded a decreasing share of *Phleum pratense* with higher intensity of stand exploitation.

Representation of other herb species in the stand

The representation of other herb species in the stand was decreasing proportionally with the increasing share of grasses after the application of fertilizers, on av. from 35.9% in 2-cut stands to 39.0% in 3-cut stands. In both variants of stand use, a statistically significant difference (P<0.05) was demonstrated in the decrease of other herb species between the unfertilized and fertilized variants (Table 2). Thus, herbs were represented mainly in the unfertilized grass stands. Gaisler et al. (1998) arrived at the same conclusion. As to the intensity of exploitation, other herbs exhibited an opposite trend than grasses, i.e. increased representation at higher intensity of use. On the other hand, their share was decreasing with the increasing order of the cut. While the proportion of other herbs in the 2-cut stands was 42.6% in the first cut, in the second cut the share significantly (P<0.05) decreased to 36.1%. The 3-cut stands showed the same trend when the share decreased from 49.5% in the first cut through 41.5% in the second cut to final 33.9% in the third cut. Differences between the individual cuts were statistically significant (P<0.05). The results (Table 4) show that a dominant species in the group of other herbs was *Polygonum bistorta* whose proportion in the stand was more or less stable regardless of the intensity of fertilization and exploitation. Observed was only a negligible increase of this species with the increasing level of fertilization, which was however statistically non-significant. The second most represented species was *Sanguisorba officinalis* whose percentage share was however markedly affected by fertilization with its proportion decreased significantly from 8.5% in the unfertilized variant to 0.9% in the variant fertilized with N180+PK. Its occurrence was also statistically significantly (P<0.05) influenced by the year, similarly as that of *Lychnis flos-cuculi*. More abundant other herb species were *Lychnis flos-cuculi*, *Carex spp.* and *Ranunculus acris*, in which a decreasing share could be observed with the increasing doses of nutrients (Table 4). The decrease was statistically significant (P<0.05) between the variants unfertilized and fertilized with nitrogen. Mrkvička and Veselá (1997) arrived at the same conclusion. The representation of *Ranunculus acer* was affected also by the intensity of exploitation and was more abundant (5.9%) in the 3-cut use than in the 2-cut use (3.7%) the difference being statistically significant (P<0.05). The results suggest that *Ranunculus acer* can resist disturbance and do better at a higher intensity of use. The resistance of *Ranunculus acer* to disturbance is documented in literature, too (Baattrup and Riis, 2004). The related species *Ranunculus auricomus* showed a similar trend being more abundant in the 3-cut mode with 6.8% while its share in the 2-cut stand was only 1.6%. This significant difference subsequently showed in the quality of the grass stand. The application of nutrients also led to changes in the representation of *Taraxacum officinale* and *Rumex acetosa* with their shares increasing with the growing supply of nutrients (Table 4). The difference was statistically significant (P<0.05) in *Taraxacum officinale*. The growing abundance of *Rumex acetosa* with the increasing intensity of fertilization is well known from literature (Niggli et al., 1993). These two species showed an increasing abundance with the increasing intensity

Table 4
Shares of dominant herb species in dependence on fertilization and intensity of exploitation in the first cut (2007-2011)

Factor	Lychnis floscuculi	Sanguisorba officinalis	Carex ssp.	Ranunculus acris	Ranunculus auricomus	Polygonum bistorta	Taraxacum officinale	Rumex acetosa
No fertilizer	4.8[a]	8.5[ab]	12.9[a]	9.0[a]	4.7	11.9	0.0[a]	1
PK	3.6[a]	13.2[a]	4.4[b]	7.0[a]	3.4	9	0.2[a]	0.7
90N+PK	0.5[b]	5.7[bc]	0.4[b]	2.0[b]	3.5	13.4	1.4[b]	2
180N+PK	0.7[b]	0.9[c]	0.8[b]	1.2[b]	5.4	15.5	1.8[b]	2.5
2007	4.8[a]	10.1[a]	3.3	4.3	4	10.8	1.2	1.7
2008	1.1[b]	10.3[a]	3	4.4	2.8	9.9	1.4	1.7
2009	0.7[b]	8.8[ab]	2.6	4.5	3.3	18.5	1.4	2.6
2010	2.6[ab]	3.3[b]	5.4	6.1	5.9	11.9	0.4	1.5
2011	2.9[ab]	3.0[b]	8.8	4.6	5.3	11.2	0.1	0.4
2-cut	2.5	7.9	5.6	3.7[a]	1.6[a]	12.8	0.7	1
3-cut	2.3	6.3	3.6	5.9[b]	6.8[b]	12.1	1.1	2.2

Average values in the same columns with different upper indices are statistically significant at a level of P<0.05

of stand exploitation, too, which was however non-significant. Klimes et al. (2003) recorded the increased share of *Taraxacum officinale* at a higher intensity of use as well.

Representation of clover crops in the stand

The least represented group in the grass stand was that of clover crops with the share of 6.5% in 2-cut stands and 8.6% in 3-cut stands. The clover crops were represented by *Trifolium repens* and *Lathyrus pratensis*. Both species showed a positive response to PK fertilization on their abundance (Table 3), which is confirmed by results of Jankovič et al. (1999) and Mrkvička and Veselá (2002). *Trifolium repens* increased from 0.6% in the unfertilized stand to 6.6% in the stand with added PK. *Lathyrus pratensis* increased from 0.2% to 2.6%, resp. The differences were statistically significant ($P<0.05$). The representation of *Trifolium repens* in the stand was also significantly affected ($P<0.05$) by the intensity of stand exploitation where the species cover increased with the increasing intensity of use from 1.3% at two cuts to 4.3% at three cuts. The higher intensity of exploitation resulted in increased light treat, which is an important growth factor for clovers (Staley and Belesky, 2004). The representation of *Trifolium repens* was significantly affected by the year, too.

A statistically significant difference in its share was found between the years 2007 (4.8%) and 2010 (0.9%). While the 2007 sum of average monthly temperatures (January-May) was the highest in the studied period (27.4°C), in 2010 it was the lowest (6.8°C) and this distinctive difference subsequently reflected also in the species' percentage share (Table 3, Figure 4). We can also observe rising trends in the increasing *Trifolium repens* cover in warm years and decreasing cover in colder years, which are however statistically non-significant. Sheppard et al. (2012) who studied the influence of increased temperatures in *Trifolium repens* similarly concluded that high temperatures exhibit a boosting effect on its growth.

Species diversity of grass stands

The highest Shannon's diversity index (Table 5) was found in unfertilized stands where it reached 2.50 in the 2-cut mode and 3.02 in the 3-cut mode. This shows that the unfertilized stands exhibited low to moderate biodiversity. The diversity index was decreasing with the increasing fertilization (Table 5, Figure 11) in both variants of exploitation to 1.74 in the 2-cut variant and 2.26 in the 3-cut variant at N180+PK, i.e. low biodiversity. The statement is supported by research results reported by Grevilliot et al. (2002) and Schadler et al. (2008). Vozár and Jankovič (2004) inform, too, that the number of species in the stand is influenced by the annual dose of nitrogen. A general trend was that the 3-cut stands exhibited higher biodiversity at the same supply of nutrients as compared with the 2-cut stands. Rysher et al. (1995) similarly reported a gradual increase of the number of species with the increasing frequency of exploitation.

Quality of grass stands

Species diversity closely relates to grass stand quality, which however showed an opposite trend as it was increasing with the growing doses of fertilizers up to N90+PK (Table 5). This phenomenon can be explained by the increased representation of cultural grasses in the stand whose feeding value is high. The explanation is supported also by Skládanka et al. (2008) who claim that the higher quality of grass stand is contributed to namely by cultural grass species such as *Alopecurus pratensis*, *Poa* spp. and *Festuca pratensis* whose occurrence in the stands was demonstrated. Furthermore, the 2-cut stands exhibited higher quality than the 3-cut stands (Figure 12) particularly due to the higher proportion of *Alopecurus pratensis*. In addition, as compared with the 2-cut stands, the 3-cut stands exhibited a significant ($P<0.05$) increase of cover by *Ranunculus acer* and *Ranunculus auricomus*, which are poisonous and thus lowering the feeding value. The fertilization level of N180+PK did not further improve the stand quality, which was by contrast slightly impaired due to the increased share of *Rumex acetosa*. Hejcman et al. (2012) confirm the trend by stating that the superfluous doping with nutrients may facilitate spreading of undesirable flora reducing the grass stand quality.

Forage yields of grass stands

Yields represented the last studied factor. In both variants of stand use, they exhibited a statistically significant produc-

Table 5
Shannon's diversity index (H), grass stand quality (E_{GQ}) and yields in 2007-2011

	Shannon's diversity index		Grass stand quality		Yields	
Factor	2-cut	3-cut	2-cut	3-cut	2-cut	3-cut
No fertilizer	2.5	3	37.3	28.4	4.2^a	4.2^a
PK	2.3	2.6	51.5	49.9	6.6^b	7.3^b
90N	1.9	2.2	69.6	63.4	7.4^c	8.1^c
180N	1.7	2.3	69.3	52.3	8.4^d	8.8^d

Average values in the same columns with different upper indices are statistically significant at a level of $P<0.05$

tion increase between the respective variants of fertilization (Table 5). The unfertilized stands featured the lowest production (4.1 $t.ha^{-1}$) and the highest production was recorded in the stands fertilized with N180+PK (8.7 $t.ha^{-1}$). Honsová et al. (2007) demonstrated the low yields in the unfertilized variants as compared with the fertilized variants, too. The greatest difference in the increase of yields was recorded between the unfertilized variant and the variant with additional PK fertilization – from 4.2 $t.ha^{-1}$ to 7.1 $t.ha^{-1}$. This increase was likely caused by the increased abundance of clover crops in the stand, which are capable of fixing atmospheric nitrogen not only for their own needs but also for other plants in the community (Adamovicz and Kladena, 2003). Kuchenmeister et al. (2012) demonstrated the relation between the increased share of clovers and yields also.

Conclusion

The high supply of nutrients showed in the increased share of *Alopecurus pratensis*; it was however considerably contributed to also by total precipitation amounts. In the studied period, we repeatedly observed falls in total precipitation amounts occurring in the month of April when the values whose long-term average had been 53.7 mm fell to mere 5.58 mm (2007) and 7.37 mm (2009). The drop subsequently reflected in the species representation. The decreased share of *Alopecurus pratensis* was compensated by increased *Poa* spp. and *Festuca rubra*, in which the overgrowth starts later and which are therefore capable of responding to rainfall in later months. Higher doses of nutrients were improving grass stand quality up to the intensity 90 $kg.ha^{-1}N$. At reaching the value of 180 $kg.ha^{-1}N$, a reversed stand quality trend occurred due to the spreading of undesirable herb species. The yields were growing with the increasing intensity of fertilization, too, with the highest biomass increase recorded at PK fertilization. The increasing doses of nutrients adversely affected biodiversity. In respect of the ascertained facts and weather fluctuations, which markedly differed from the long-term average, in spring months in particular, we can recommend as an optimal dose 90 $kg.ha^{-1}N$ combined with 2-cut exploitation for achieving high quality of the grass stand over a long-term period. The 3-cut mode appears as the most suitable for the biodiversity preservation. The additional supply of other deficient nutrients, namely phosphorus, which is wanting on local acidic soils, should be a matter of course.

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References

Adamovics, A. and V. Kladena, 2003. Symbiotically Fixed Nitrogen in the Soils of Latvia: Possibilities and Problems. *4th International Scientific and Practical Conference on Environment Technology Resources*, Rezekne, LATVIA, pp. 13-17.

Baattrup-Pedersen, A. and T. Riis, 2004. Impacts of different weed cutting practices on macrophyte species diversity and composition in a Danish stream. *River Research and Applications*, **20:** 103-114.

Bandurska, H. and W. Jozwiak, 2010. A Comparison of the Effects of Drought on Proline Accumulation and Peroxidases Activity in Leaves of *Festuca rubra* L. and *Lolium perence*. *Acta Societatis Botanicorum Poliniae,* **79:** 111-116.

Begon M., 1997. *Ekologie - Jedinci, populace a společenstva*. Vydavatelství Univerzity Palackého, Olomouc, 949 pp.

Busey, P., 2003. Cultural management of weeds in turfgrass: A review. *Crop Science*, **43:** 1899-1911.

Camska, R. and H. Skálová, 2012. Effect of low-dose N application and early mowing on plant species composition of mesophilous meadow grassland (Arrhenatherion) in Central Europe. *Grass and Forage Science,* **67:** 403-410.

Fiala, J., A. Kohoutek and J. Klír, 2007. *Výživa a hnojení travních a jetelotravních porostů*. Výzkumný ústav rostlinné výroby, Praha, 36 pp. (Cz).

Gaisler, J., J. Fiala and B. Spoustová, 1998. The Changes of Botanical Composition Yield in Dependence on the Type of Grassland and Fertilization. *Rostlinná výroba,* **44:** 39-44 (Cz).

Garnier, E., M. L. Navas, M. P. Austin, J. M. Lilley and R. M. Gifford, 1997. A Problem for Diversity-Productivity studies: How to Compare the Productivity of Multispecific Plant Mixtures to that of Monocultures? *Acta Oecologica*, **18:** 657-670.

Gastal, F., L. A. Dawson and B. Thornton, 2010. Responses of plant traits of four grasses from contrasting habitats to defoliation and N supply. *Nutrient Cycling in Agroecosystems*, **88:** 245-258.

Gotze, C., A. Jung, I. Merbach, R. Wennrich and C. Glasser, 2010. Spectrometric analyses in comparison to the physiological condition of heavy metal stressed floodplain vegetation in a standardised experiment. *Central Eropean Journal of Geoscientic,* **2**: 132-137.

Grevilliot, F. and S. Miller, 2002. Grassland ecotopes of the upper Meuse as references for habitats and biodiversity restoration: A synthesi. *Landscape Ecology*, **17:** 19-33.

Hanze, L., I. Ilavská and N. Britaňák, 2004. Effect of Minerál Fertilisation on the Above-Ground Biomass and Root systém Production of Permanent Grassland. *Acta Fytotechnica et Zootechnica*, **7:** 78-83.

Hejcman, M., L. Strnad, P. Hejcmanová and V. Pavlu, V., 2012. Response of plant species composition, biomass production and biomass chemical properties to high N, P and K application rates in *Dactylis glomerata*- and *Festuca arundinacea*-dominated grassland. *Grass and Forage Science*, **67:** 488-506.

Honsova, D., M. Hejcman, M. Klaudisova, V. Pavlu, D. Kocourkova and J. Hakl, 2007. Species composition of an alluvial meadow after 40 years of applying nitrogen, phospohorus and potassium fertilizer. *Preslia*, **79:** 245-258.

Chapman, R., 2001. Recreated Botanical Diverse Grassland. In: Tow, P.G. and Lazebny, A., Competion and Succession in Pastures, *CAB International*, Wallingford, UK, pp. 261-282.

Jancovic, J., R. Holubek and J. Santrucek, 1999. Botanical and production changes of permanent grassland after cessation of mineral fertilization. *Rostlinná výroba*, **45:** 3-27 (Cz).

Kampmann, D., A. Lüscher, W. Konold and F. Herzog, 2011. Agri-Environment Schneme Protects Diversity of Mountain Grassland Species. *Land Use Policy*, **29:** 569-576.

Klimes, F., L. Kolar, M. Kobes and B. Vozenilkova, 2003. The impacts of various cultivation methods and permanent grassland use on the changes in *Taraxacum officinale* Web. cover rate. *Plant Soil and Environment*, **49:** 49-54.

Kramberger, B., A. Gselman, A. Borec and M. Kaligaric, 2005. Periodic very late cut of permanent grassland as a measure to facilitate self-reseeding of grasses. *Berichte uber Landwirtschaft*, **83:** 431-446.

Kuchenmeister, F., K. Kuchenmeister, N. Wrage, M. Kayser and J. Isselstein, 2012. Yield and yield stability in mixtures of productive grassland species: Does species number or functional group composition matter? *Grassland Science,* **58:** 94-100.

Lapinshiene, N., 1998. Effect of reclaimation on the dynamics of aboveground and underground phytomass of cultured meadow communities in different ecotypes of Lithuania. *Developments in Plant and Soil,* **82:** 61-73.

Mrkvicka, J. and M. Vesela, M., 1997. Progress of yields and botanical composion of permanent meadow stands in absence of N-fertilization. *Rostlinná výroba*, **43:** 565-570 (Cz).

Mrkvicka, J. and M. Vesela, 2002. Influence of Fertilization Rates on Species Composition, Duality and Yields of the Meadow Fodder. *Rostlinná výroba*, **48:** 494-498 (Cz).

Niggli, U., J. Nosberger and J. Lehmann, 1993. Effects of Nitrogen-Fertilization and Cutting Frequency on the Competitive Ability and the Regrowth Capacity of *Rumex-Obtusifolius L*. in Several Grass Swards. *Weed Research*, **33:** 131-137.

Nissinen, O. and H. Hakkola, 1995. Effects of plant species and harvesting system on grassland production in northern Finland. *Agricultural Science in Finland*, **4:** 479-495.

Novák, J., 2004. Evaluation of Grassland Quality. *Ecologia*, **23:** 127-143.

Ruemele, B. A., L. A. Brilman and D. R. Hurd, 1995. Fine Fescue Gernplasm Diversity and Vulnerability. *Crop Science*, **35:** 313-316.

Rysher, P., R. Langenauer and A. Gigon, 1995. Species Richness and Vegetation Structure in a Limestone Grassland after 15 years Management with Six Biomass Removal Regimes. *Folia Geobot. Phytotax*, pp. 157-167.

Sheppard, C. S., J. M. Alexander and R. Billeter, 2012. The Invasion of Plant Communities Following Extreme Weather Events under Ambient and Elevated Temperature. *Plant Ecology*, **213** (8): 1289-1301.

Schadler, M., T. Rottstock and R. Brandl, 2008. Do nutrients and invertebrate herbivory interact in an artificial plant community? *Basic and Applied Ecology*, **9:** 550-559.

Schmiede, R., A. Otte and T. W. Donath, 2012. Enhancing Plant Biodiversity in Species-Poor Grassland through Plant Materiál Transfer-the Impact of Sard Distance. *Applied Vegetation Science*, **15:** 290-298.

Skládanka, J., F. Hrabe and P. Heger, 2008. Vliv intenzity hnojení a využití na druhovou diverzitu a kvalitu travního porostu. Acta Universitatis agriculturae et silviculturae Mendelianae brunensis, Brno, 2: 131-138.

Smith, R. S., H. Buckingham, M. J. Bullard, R. S. Shield and A. Younger, 1996. The conservation management of mesotrophic (meadow) grassland in northern England.1. Effects of grazing, cutting date and fertilizer on the vegetation of a traditionally managed Sward. *Grass and Forage Science*, **51:** 278-291.

Staley, T. E. and D. P. Belesky, 2004. Nodulation and root growth of forage legumes sown into tall fescue swards. *Grass and Forage Science*, **59:** 399-405.

Veselá, M. and J. Mrkvička, 2002. Výnosy a kvalita píce z travních porostu. *Úroda*, **50:** 14-15.

Vozár, L. and J. Jankovič, 2004. Diverzita antropogénne ovplyvnenej asociáce *Lolio-Cynosuretum Typicum* R.Tx. 1937 (Diversity of anthropogenic impacted association *Lolio-Cynosuretum Typicum* R.Tx. 1937). In: Produkčné, ekologické a krajinotvorné funkcie trávnych ekosystémov a krmných plodín. Nitra: SPU Nitra, pp. 136-143.

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