The effect of fertilization and weather conditions on the yield of forage and species diversity

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Abstract: The importance of grassland consists not only in forage production but also in non-production functions. Grasslads are particulary important due to high level of biodiversity. For farmers are species rich grasslands less productive and less quality. Nevertheless, these grasslands provide more stable yields and the forage is tastier for livestock. Both agronomists and environmentalists have tackled question whether the productivity of plant communities really depends on the species diversity. The aim of this study was to compare the effect of fertilization and weather conditions on the species diversity and yield of forage. Another goal was to explore if there is a relationship between yield of forage and species diversity. The yields of forage were growing with the increasing intensity of fertilization ($P<0.05$). On the other hand diversity index was statistically significant lower ($P<0.05$) in the variants with added of nitrogen in comparison with PK variant. The results showed that there existed negative relationship between yield of forage and diversity index.

Key-Words: nutrients, Shannon's diversity index, species richness, biomass

Introduction

The origin of grassland in the Czech territory is associated with the production function [1]. Their importance as a source of feed grow with an increasing altitude [2]. The production function in grassland is still crucial, but due to the decline of cattle in the past twenty years [3] are seeking new uses in the form of non-production functions such as soil protection, conservation of water quality, aesthetic and recreational functions [4, 5]. These functions are mainly associated with grassland biodiversity. Meadows and pastures represent a significant source of biodiversity and can host up to two thirds of all species of regional flora [6].

For farmers are species rich grasslands less productive and less quality. Nevertheless, these grasslands provide more stable yields and the forage is tastier for livestock. Both agronomists and environmentalists have tackled question whether the productivity of plant communities really depends on the species diversity [7].

The aim of this study was to compare the effect of fertilization and weather conditions on the species diversity and yield of forage. Another goal was to explore if there is a relationship between yield of forage and species diversity.

Material and Methods

The experimental plot was established in the cadastre of the village Kameničky belonging in the Protected Landscape Area of Žďárské vrchy Hills. Experimental works were launched there in 1992. The presented results include the years from 2009-2013. 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 annual precipitation amount is 758.4mm. Soil type is acidic Luvic Stagnosol on the gneiss diluvium. The experiment was designed by using the method of split compartments in four repetitions. The evaluated factor was fertilization (no fertilization, PK fertilization, 90N+PK fertilization and 180N+PK fertilization). The stands were exploited in the system of three cuts. Nitrogen was supplied in the form of ammonium nitrate with limestone (LAV 27%) at a total dose of 90kg.ha^{-1} N resp. 180kg.ha^{-1} N. In the mode of three cuts, the nitrogen dose was applied in three terms (1/3 in spring, 1/3 after 1st cut and 1/3 after 2nd cut). Potassic and phosphoric fertilizers were applied in spring. Phosphorus was applied in the form of superphosphate (26%) at 30 kg.ha^{-1} P and potassium was applied in the form of potassium salt (60%) at 60 kg.ha^{-1} K. The stands were harvested in three terms (early June, early

August and early October). The grass was harvested by the mower Model MF-70 equipped with a cutting bar (engagement 1.2m).

In order to establish the share of individual species in the harvested forage, samples were taken of above-ground biomass from permanently staked plots (0.25m^2). The samples of the above-ground forage biomass were sorted out into individual species and dried at 60 °C. Subsequently, their dry weight was established 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.

Shannon's diversity index (H) was calculated according to the below formula [17]:

$$H = -\sum_{i=1}^{S} Pi\,(\ln Pi)$$

where H is diversity index and P_i is the share of the ith species in the stand

The determination of the production efficiency of 1 kg supplied nutrients (DPE) in kg of dry matter.1kg nutrients^{-1} was calculated according to the following formula:

$$DPE = \frac{\text{yield of forage no fertilized stand} - \text{yield of forage fertilized stand}}{\text{the amount of added nutrients}}$$

Statistical evaluation was conducted with using Statistica 10 programme by multi-factorial analysis of variance (ANOVA) with Post-Hoc Fischer LSD test. The evaluation of relationship between yield of forage and diversity index was performed with using the correlation analysis.

Results and Discussion

The highest yield of forage was reached in the 180N+PK variant, namely 7.6 t.ha^{-1} while in the unfertilized variant was the average yield of forage lowest, only 3.6 t.ha^{-1} (Table 1). The highest increase in production was recorded by PK fertilizing. This is evidenced by the highest efficiency of nutrient utilization on this variant – there was growth of 27.8 kg.ha^{-1} biomass after supplying 1 kg.ha^{-1} of nutrients. Also REGAL and VESELÁ [8] reached similar values. When dosage of supplied nutrients was increasing, efficiency of nutrient utilization was decreasing to 16.1 kg.ha^{-1} in the variant fertilized with 90N+PK and to 14.8 kg.ha^{-1} in the 180N+PK variant. The fertilizing had significantly positive effect on production of dry matter ($P<0.05$). This conclusion is also consistent with findings of other authors [9, 10, 11]. The yields were affected also by year, namely annual precipitation amounts and average annual temperature, though statistically insignificantly (Table 2). Also HREVUŠOVÁ [12] recorded changes in production due to year. The highest production of dry matter was recorded in 2011, namely 7 t.ha^{-1}. In this year was recorded the highest average annual temperature for the entire observed period (Figure 1). On the other hand the precipitation amounts of this year were below average of long-term precipitation amounts in period 1981-2010 (Figure 2). The lowest dry matter yield was recorded in 2010 (5 t.ha^{-1}). This year, by contrast, was characterized by lower average annual temperature and higher annual precipitation amounts than the long-term averages. DAŇHELKA and HONSOVÁ [13] reported that yields on the site of mesohygrophytic character are more affected by air temperature than total precipitation.

The effect of fertilization was also observed in values of Shannon's diversity index. The highest value of diversity index H=2.4 was recorded in the variant with PK. Conversely both variants with nitrogen showed the lowest value H=2 (Table 1). The difference between these variants and the PK variant was also statistically significant ($P<0.05$). This statement is also supported with results of other authors [14, 15]. The PK variant showed also the most species, namely 23. Significantly ($P<0.05$) the least species, in comparison with PK variant, was found in the 180N+PK variant, namely 19. HOLÚBEK [16] adds that when the doses of fertilizers are higher, the changes in species composition are more pronounced. Although there were average 20 species at 90N+PK variant, which is the same as at the not fertilized variant, there was observed a lower value of diversity index. The explanation for this seems to be the fact that diversity index depends not only on the species richness but also on an equability of the community. At the variants supplied with nitrogen are more supported nitrophilous species that increasingly dominate and equability of this community is declining. According to BEGON et al. [17] the unbalanced species richer community may have even lower diversity index than species-poor community, but well balanced.

Table 1 The influence of fertilization on the diversity index, species richness and a yield of forage

Evaluated characteristic	No fertilization	PK	90N+PK	180N+PK
Shannon's diversity index (H)	2.2^{ab}	2.4^{a}	2^{b}	2^{b}
Number of species	20^{ab}	23^{a}	20^{ab}	19^{b}
Yield of forage t.ha^{-1}	3.6^{a}	6.1^{b}	6.5^{b}	7.6^{c}

Different letters in the rows indicate statistically significant differences at a level of P<0.05

Table 2 The influence of year on the diversity index, species richness and a yield of forage

Evaluated characteristic	2009	2010	2011	2012	2013	Average
Shannon's diversity index (H)	2	2.2	2.1	2.2	2.3	2.2
Number of species	20	19	19	21	22	20
Yield of forage t.ha^{-1}	6	5	7	6.3	5.6	5.9

Also the year had impact on the value of diversity index (Table 2). The highest average diversity index was recorded in 2013 (H=2.3). On the other hand in year 2009 was the diversity index lowest (H=2.0). When comparing values of diversity index with climatic conditions of the particular year (Figure 1, 2) it seems that diversity index is probably more affected by relationships in the community rather than by the weather conditions.

If we compare the averages of diversity index with averages of forage production (Table 2), we can repeatedly observe that in some years with higher diversity indexes were recorded lower dry matter yields. Although there was identified only weak indirect relationship (r = -0.2724). Also ROSE and LEUSCHNER [18] describe the negative impact of species diversity on yield of forage. Conversely, TANG et al. [19] states that biodiversity supports productivity of communities.

Fig. 1 The comparison of average annual temperature with long-term average

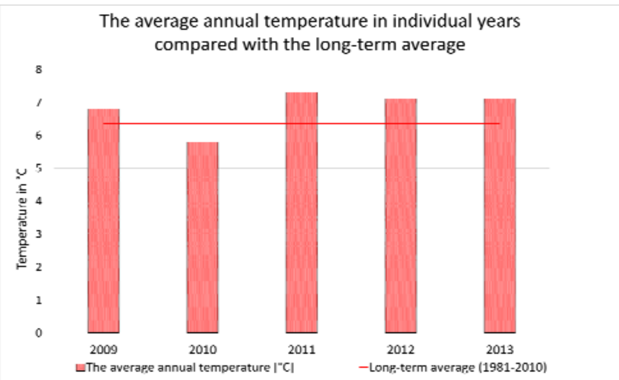
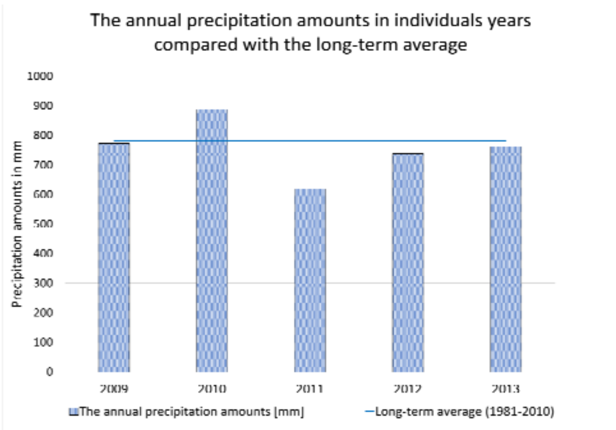


Fig. 2 The comparison of annual precipitation amounts with long-term average



Conclusion

Fertilizing has significant effect (P<0.05) on increase in the forage production. The highest efficiency of nutrient utilization was found at PK variant, namely 27.8 kg.ha^{-1} by dosage 1 kg of nutrients per 1 ha. The year had also influence – higher yields was repeatedly recorded in years with higher average annual temperature and lower annual precipitation amounts. From results it appears that for production is more important annual average temperature than the precipitation amounts, probably due to a sufficiently high level of groundwater throughout the whole year. Excessive rainfall totals can then have a negative impact on the production. The highest species diversity (H=2.4) was found in variants subsidized by PK. On the contrary, the variants subsidized by a nitrogen had the lowest diversity index (H=2). Moreover, this difference was statistically significant (P<0.05).

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