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EVALUATION OF THE EFFECT OF VARIOUS SYSTEMS OF EXTENSIVE UTILIZATION ON THE SPECIES DIVERSITY OF GRASSLANDS

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Abstract. Preserving grassland biodiversity requires their proper utilization. In many cases, especially in protected areas, preserving species diversity becomes the main task of cultivation measures. The aim of this study was to compare the effect of several utilization systems of low intensity on changes in sward species composition. The experiment was carried out during 2001-2007 in the vicinity of Kraków (Bielany, 50°02' N; 19°50' E), on sandy soil of low fertility. Four ways of fertilization was applied. The sward was cut at two times – at the beginning of June and at the end of July. In spite of a considerable increase in yield under the influence of fertilization, no statistically significant effect of the utilization system on the number of species and Shannon-Wiener diversity index was observed. Differences in the share of the most important species (red fescue, Yorkshire fog and yarrow) were greater between particular years of the experiment than between the treatments. One of the reasons for the lack of the effect of various utilization systems on species diversity could be the impossibility of the appearance of meadow species diasporas from the neighborhood. In conclusion it was found that additional sowing of selected meadow species can be necessary for regeneration of multi-species meadow communities.

Key words: diversity index, grassland management, protected areas, red fescue, yarrow, Yorkshire fog

INTRODUCTION

Grasslands are presently regarded as an important place of protecting numerous species of plants and animals related to them. Many meadow communities occurring in Poland are included in Annex I of the Habitats Directive EU as natural habitats of common importance [Council Directive...]. Communities rich in species are of particular natural value. Unfortunately, a large proportion of meadows and pastures is characterized by small species diversity. In many cases a small number of species is

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a typical feature of some plant communities, such as pastures (the association *Lolio-Cynosuretum*). However, decreasing biodiversity of the previously multi-species communities has also been observed in recent years both in Europe [Pärtel et al. 2005] and in Poland [Szoszkiewicz and Szoszkiewicz 1998, Kryszak 2001, Trąba et al. 2006] This usually results from increasing management intensity and mostly from the application of nitrogen fertilization. This phenomenon is frequently observed in West Europe [Walker et al. 2004]. In Poland, changing of the traditional way of utilization, particularly the earlier time of the first cut and replacing farmyard manure with mineral fertilization, seems to be the main cause of a decrease in species diversity of grasslands. To the largest extent, however, a decrease in species diversity is caused by complete abandoning of cutting or grazing [Stypiński et al. 2009].

Thus, the preservation of meadow communities requires conducting proper measures, adapted to particular habitat conditions [Perzanowska and Mróz 2003, Gibbon 2005]. The functional aspect, that is the yield height and its fodder usefulness, do not play an essential role in such cases. What is more, a reduction in yield is favorable, due to the impossibility of managing the generated biomass, which takes place especially in protected areas [Wróbel 2000].

The aim of this study was to develop a variant of meadow management which will increase the species diversity of the sward, preserving small yielding level.

MATERIAL AND METHODS

The experiment was carried out in 2001-2007 near Kraków at Bielany (50°02' N; 19°50' E), in the fields of the experimental station UR in Kraków on grassland formed from self-sodding of former arable lands. Red fescue and Yorkshire fog predominated in the sward. The experiment was established in the randomized blocks design in three replications. The area of plots was 9 m^2. Different utilization systems selected on the basis of various studies [Nösberger and Rodriguez 1996, Perzanowska and Mróz 2003] were used as treatments: 1 – without measures; 2 – late cutting, without fertilization; 3 – early cutting, without fertilization; 4 – two-time cutting, without fertilization; 5 – self-sodding after oats cultivation, late cutting, without fertilization; 6 – late cutting, fertilization with the biomass from the previous year; 7 – late cutting, fertilization with PK; 8 – late cutting every 2^{nd} year, without fertilization; 9 – late cutting, fertilization with NPK; 10 – late cutting, fertilization with farmyard manure. Mineral fertilization was applied in spring at the amount: P – 17.2 $kg \cdot ha^{-1}$, K – 33.2 $kg \cdot ha^{-1}$, N – 35 $kg \cdot ha^{-1}$. The plots were fertilized in autumn with partially decomposed biomass from the previous year and with farmyard manure at an amount of 10 t ha^{-1}, at first every year and from 2004 every second year. The early cutting fell at the beginning of June and the late cutting at the end of July. Harvest of the second cutting was gathered in the middle of September. After cutting, the dry weight yield was estimated. Before the cut, the species composition of the sward was determined using the scale of Braun-Blanquet. Based on this, the share of individual species in the ground cover was assessed. Species diversity was presented as the number of species on a plot and the Shannon-Wiener species diversity index [Magurran 1988]. For the estimation of changes in composition after 7 years of the experiment, detrended correspondence analysis (DCA) was applied using the program Canoco. For each plot, the length of gradient was calculated characterizing the range of species exchange (β-diversity) along the axis presenting the direction of the main variability [Leps and Smilauer 2003]. The other statistical analyses, i.e. the analysis of variance with testing difference with the Duncan test and charts were made using the program Statistica (StatSoft, Inc. 2008).

RESULTS

The yields obtained were relatively low and considerably varied in individual years. The highest mean yield was gathered in 2002 (4.0 $t\cdot ha^{-1}$), and the lowest in 2007 (1.7 $t\cdot ha^{-1}$) (Table 1). A tendency for a decrease in yield in successive years can be seen. The highest yields were obtained from the fertilized plots, whereas on the other treatments the differences were very small. Only in 2003 no statistically significant differences were found between the treatments.

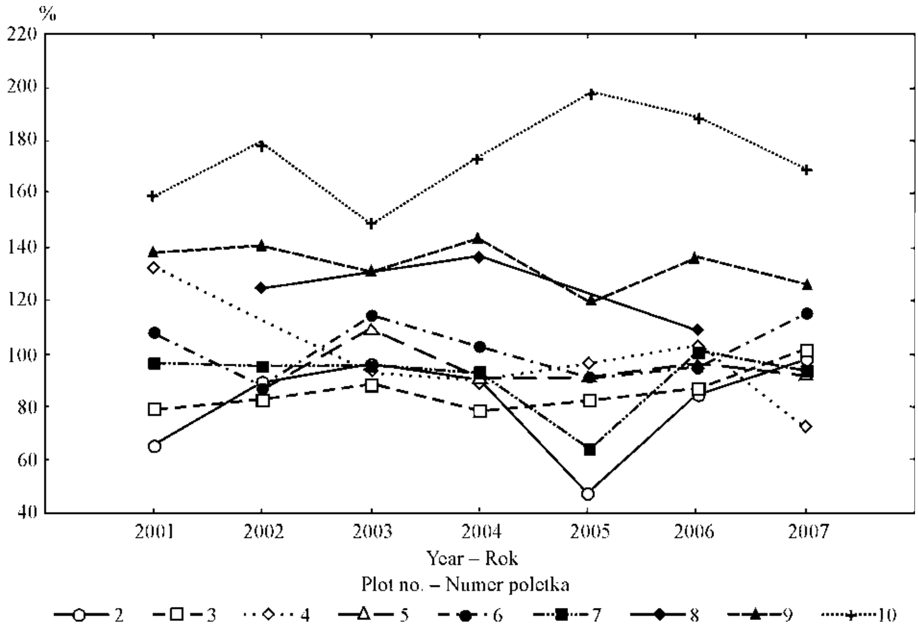
Table 1. Dry matter yield, $t\cdot ha^{-1}$
Tabela 1. Plon suchej masy, $t\cdot ha^{-1}$

Treatment Obiekt	Year – Rok							Mean Średnia
	2001	2002	2003	2004	2005	2006	2007	
1	nk	nk	nk	nk	nk	nk	nk	nk
2	2.0 a	3.2 a	2.4 a	1.7 a	1.5 a	1.4 a	1.4 b	2.0
3	2.4 ab	3.0 a	2.2 a	1.5 a	2.6 abc	1.5 a	1.5 bc	2.1
4	4.1 cd	4.0 ab	2.3 a	1.7 a	3.0 bc	1.7 ab	1.1 a	2.6
5	nk	3.1 a	2.7 a	1.7 a	2.8 bc	1.6 a	1.4 b	2.3
6	3.3 bc	3.1 a	2.8 a	1.9 a	2.8 bc	1.6 a	1.7 cd	2.5
7	2.9 ab	3.4 ab	2.3 a	1.7 a	2.0 ab	1.7 a	1.4 b	2.2
8	nk	4.4 ab	nk	2.5 b	nk	1.8 ab	nk	2.9
9	4.2 cd	5.0 bc	3.2 a	2.7 b	3.7 c	2.3 b	1.9 d	3.4
10	4.8 d	6.4 c	3.7 a	3.2 c	6.1 d	3.2 c	2.5 e	4.4
Mean Średnia	3.4	4.0	2.7	2.1	3.1	1.9	1.7	2.7

nk – no cuts – nie koszone
treatment no. 5 in 2001 oats cultivation – obiekt nr 5 w 2001 r. – uprawa owsa
values in a column denoted with same letters do not differ significantly (Duncan's test, P = 0.05) – dane dotyczące tego samego roku oznaczone tą samą literą nie różnią się istotnie (test Duncana P = 0,05)

A comparison of the effect of particular utilization systems on the relative yield height (% of mean yield for all the treatments) in successive years (Fig. 1) indicates that the highest yields in relation to the others were obtained on treatments fertilized with farmyard manure, with full mineral fertilization and cut every second year. The plots cut twice show a noticeable downward tendency. The effect of the other utilization systems on yield is not proved statistically.

The total number of species occurring on the plots was very low and amounted to 51, of which 23 are species recorded sporadically less than 10 times during the experiment. The mean number of species per plot was from 8.7 to 16.7 and did not show an upward tendency in successive years, at any utilization system (Table 2). Quite the opposite, in the first year of the experiment the largest number of species was recorded on many plots. Differences in the number of species in the final year of the experiment are not large. The treatments which were not cut and cut every second year were characterized by the smallest number of species. The highest number of species was observed for the treatment fertilized with composted biomass and for the other fertilized treatment. The differences between them, however, were small.



treatment no. 1 was not cut – obiekt nr 1 nie był koszony

Fig. 1. Relative yield [% o mean dry matter yield for each year]
Rys. 1. Plon względny [% średniego plonu s.m. dla danego roku]

Table 2. Mean number of plant species
Tabela 2. Średnia liczba gatunków roślin

Treatment Obiekt	Year – Rok						
	2001	2002	2003	2004	2005	2006	2007
1	11.0 a	9.7 a	7.0 a	8.3 a	10.3 a	10.7 a	8.7 a
2	13.3 a	12.0 a	11.3 a	11.3 a	14.0 a	12.0 a	9.7 ab
3	13.3 a	9.3 a	9.7 a	11.7 a	11.3 a	11.7 a	10.3 abc
4	13.0 a	11.7 a	10.3 a	12.0 a	15.0 a	11.7 a	12.7 bc
5	–	9.7 a	10.3 a	10.0 a	12.0 a	11.3 a	11.7 abc
6	11.7 a	10.0 a	9.0 a	11.7 a	13.0 a	13.7 a	13.7 c
7	15.0 a	13.7 a	11.3 a	12.0 a	13.7 a	11.0 a	11.3 abc
8	16.7 a	11.0 a	9.3 a	8.3 a	11.0 a	11.7 a	9.0 a
9	14.0 a	10.7 a	9.3 a	9.0 a	9.7 a	9.7 a	10.0 ab
10	14.3 a	10.7 a	10.0 a	12.3 a	14.7 a	12.3 a	12.0 abc

for explanations, see Table 1 – objaśnienia w tabeli 1

The Shannon-Wiener diversity index showed considerably higher fluctuations than the number of species (Table 3). Nevertheless, just as with the number of species, no clear tendencies were observed in successive years. The plots which were not cut were characterized by a considerable lowest diversity and this index reached the highest values for the plots fertilized with farmyard manure.

Table 3. Shannon-Wiener diversity index
Tabela 3. Współczynnik różnorodności Shannona-Wienera

Treatment Obiekt	Year – Rok						
	2001	2002	2003	2004	2005	2006	2007
1	1.11 a	1.06 a	0.31 a	0.84 a	0.98 a	1.24 ab	1.19 a
2	1.56 bc	1.46 a	1.44 bc	1.21 ab	1.58 bcd	1.54 bc	1.43 ab
3	1.41 abc	1.32 a	1.46 bc	1.56 bc	1.57 bcd	1.51 abc	1.45 ab
4	1.46 abc	1.42 a	1.42 bc	1.68 bc	1.98 d	1.63 bc	1.45 ab
5	–	1.43 a	1.31 bc	1.34 abc	1.59 bcd	1.67 bc	1.65 b
6	1.36 abc	1.37 a	1.75 c	1.61 bc	1.84 cd	1.80 c	1.53 ab
7	1.65 bc	1.18 a	1.16 b	1.50 bc	1.61 bcd	1.53 bc	1.65 b
8	1.80 c	1.39 a	1.54 bc	1.44 bc	1.79 cd	1.27 ab	1.48 ab
9	1.57 bc	1.34 a	1.23 bc	1.18 ab	1.22 ab	1.10 a	1.19 a
10	1.38 ab	1.36 a	1.31 bc	1.80 c	1.87 cd	1.88 c	1.76 b

for explanations, see Table 1 – objaśnienia w tabeli 1

In spite of slight changes in species composition on particular plots, considerable changes in the share of the main species were observed in individual years. Three species predominated in the sward of all the experimental treatments: red fescue (*Festuca rubra*), Yorkshire fog (*Holcus lanatus*) and yarrow (*Achillea millefolium*). In the first years red fescue almost completely dominated the plots which were not cut (Fig. 2), whereas later the proportion of this species slightly decreased. A slight but constant upward tendency in the share of this species was observed on the plots with full mineral fertilization and those subject to self-sodding after oats cultivation. Yorkshire fog (Fig. 3) obtained the highest share on plots subject to self-sodding, but this proportion decreased quickly in successive years. In the case of plots fertilized with farmyard manure, almost complete disappearance of this species was noted in 2003 and 2004, whereas later this share increased constantly. No effect of the utilization system on the share of yarrow in the sward was observed (Fig. 4). This share changed considerably in individual years but it was hardly related with the utilization system.

Detrended correspondence analysis (DCA) applied for plots in the 7th year of the experiment showed a large diversification of individual plots within the same utilization system (Table 4). The total variance and the length of gradient of changes in composition during 7 years of the experiment was calculated for individual plots. The least variance was from 0.320 for the plot subject to self-sodding to 0.737 for the plot cut without fertilization. The length of gradient was from 0.930 for the plot fertilized with biomass from the previous year to 1.660 for a plot cut twice. However, no statistically significant differences were found in those indexes for individual utilization systems.

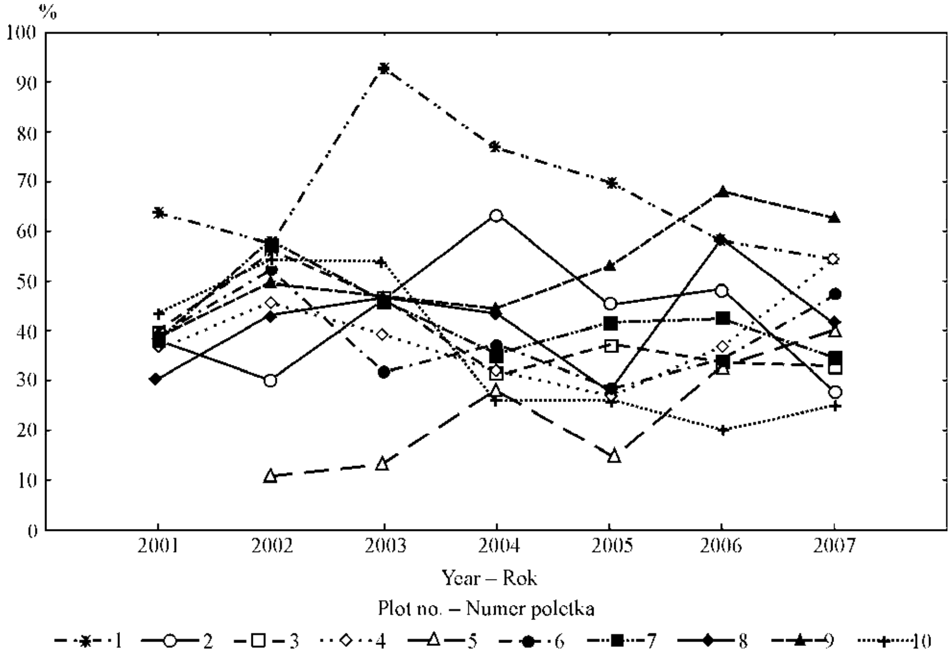


Fig. 2. Share of red fescue in ground cover
Rys. 2. Udział kostrzewy czerwonej w pokryciu powierzchni

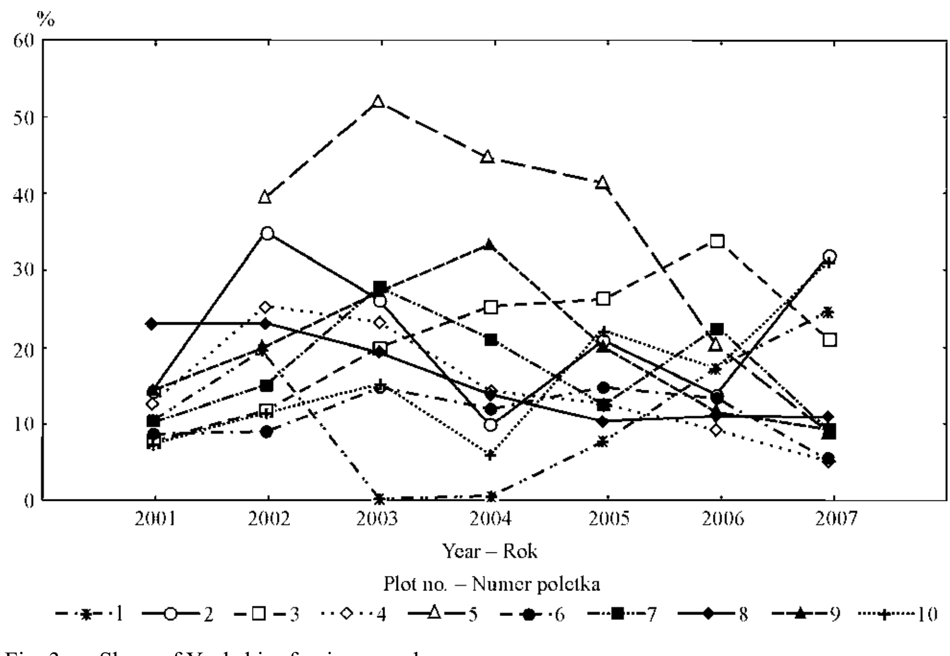


Fig. 3. Share of Yorkshire fog in ground cover
Rys. 3. Udział kłosówki wełnistej w pokryciu powierzchni

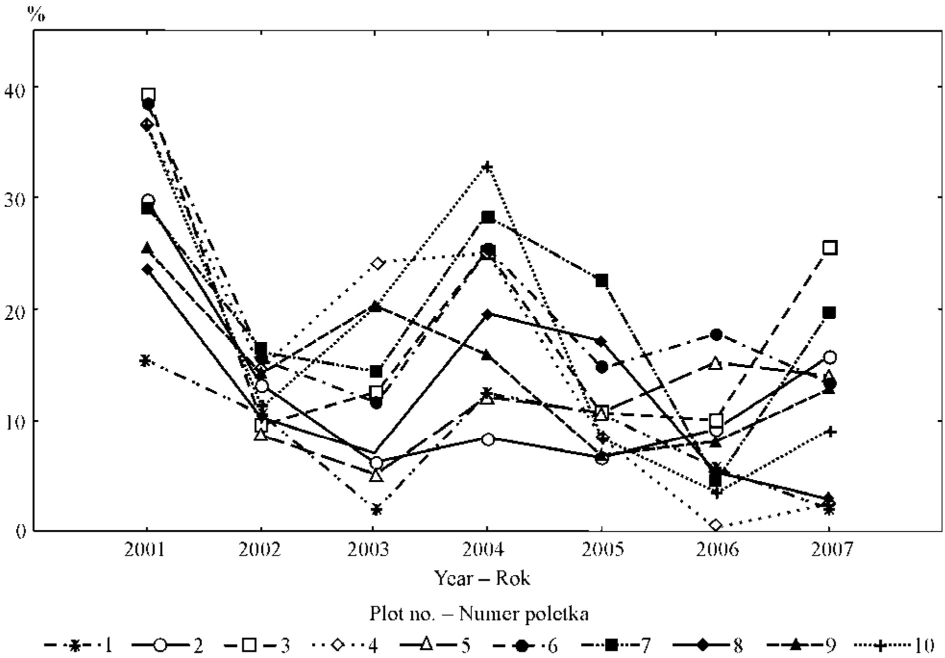


Fig. 4. Share of yarrow in ground cover
Rys. 4. Udział krwawnika pospolitego w pokryciu powierzchni

Table 4. Changes of species composition on plots during 7 years of experiment obtained with DCA method
Tabela 4. Ocena zmienności składu gatunkowego na poszczególnych poletkach w ciągu 7 lat uzyskana metodą DCA

Treatment Obiekt	Total variance Wariancja całkowita			Length of gradient (standard deviation) Długość gradientu (odchylenie standardowe)		
	plot no. – numer poletka					
	1	2	3	1	2	3
1	0.445	0.724	0.610	1.07	1.43	1.33
2	0.374	0.561	0.429	1.24	1.26	1.08
3	0.557	0.737	0.403	1.54	1.41	1.17
4	0.641	0.624	0.662	1.66	1.51	1.55
5	0.320	0.546	0.541	1.10	1.37	1.42
6	0.613	0.334	0.530	1.58	0.93	1.43
7	0.495	0.455	0.616	1.22	1.15	1.55
8	0.463	0.456	0.652	1.51	1.12	1.39
9	0.411	0.471	0.529	1.00	1.24	1.24
10	0.431	0.540	0.561	1.40	1.44	1.49

DISCUSSION

Decided changes in species diversity did not occur during 7 years of the experiment. The lengths of gradient DCA calculated, being the measure of the changes on individual plots, are small. It is assumed that at a length of gradient of about 4 SD (standard deviation) [Leps and Smilauer 2003] the total exchange of species occurs, whereas in this experiment they did not exceed 1.66 of standard deviation. On many plots, different direction of those changes was observed at the same utilization system, which suggests rather random variability of species composition than the effect of utilization.

None of the systems applied in the experiment had a decisive effect on an increase of the species number and diversity of the sward. Diversification of the Shannon-Wiener diversity index was higher than that of the species number. The Shannon-Wiener index considers the share of individual species in the ground cover. The share in ground cover is considerably more affected by various factors, particularly the weather conditions, than the appearance and vanishing of species. It can be observed that abandoning utilization has a definitely negative effect on the number of species. This is confirmed by the results of many studies – utilization of semi-natural meadows ecosystems is necessary to preserve them [Bakker 1989, Kostuch and Piorunek 2001]. Also cutting every second year, which is sometimes recommended, in this case resulted in a decrease in the number of species. The times of cutting and fertilization rates applied in this experiment had a relatively small effect on a change in the species composition of individual plots. One of the main causes seems to be a relatively small diversification of the measures applied. A significant effect of the utilization system was usually observed comparing such measures as grazing, cutting and mulching as well as burning [Moog et al. 2002]. The level of fertilization, generally limiting species diversity, was originally very low and aimed only to prevent the excessive nutrient deficiency of soil. The fertilization applied, especially organic, resulted in a significant increase in yield. The majority of studies conducted in Poland and Europe indicated a negative effect of fertilization on the species diversity of grasslands. An increase in the availability of nutrients results in competitive elimination of many small species by nitrofilous plants [Bobbink et al. 1998]. They are more productive, generate much biomass and compete with more weekly growing species for light and nutrients [Marrs et al. 1993]. These studies usually considered much more fertile habitats and application considerably more fertilization rates. Under conditions of poor, sandy soils that occurred in the experiment, increasing fertility, or for instance its keeping by returning the nutrients taken with yield, can have a favourable effect on the number of occurring species. Increasing species diversity along with an increase in fertility of poor habitats and a decrease in this diversity along with an increase in fertility of fertile habitats was observed in grasslands of the Beskid Sądecki mountains [Kopeć et al. 2010].

The fluctuations in the number of species observed were small and not related to the utilization system but to the year of observation. Usually annual species and those typical of other types of communities (e.g. weeds of arable land) appeared in the sward and vanished. Plant communities of grasslands are characterized by considerable fluctuations of species composition in individual years. This is usually connected with the course of weather conditions which most frequently act through the effect of precipitation level on the development of biomass [Silverton et al. 1994, Kasperczyk and Szewczyk 2007], and the amount of biomass is regarded as one of most important factors affecting the number of species in the community [Marrs et al. 1993]. It seems that in the experiment the effect of habitat factors was larger than that of the measures applied. Presumably, the diversifying effect of measures would have a chance to emerge during the period of their application longer than seven years.

A low number of species and the lack of new ones appearing also result from soil conditions, which do not favor forming species-rich meadow communities. Meadow communities formed on unfertile, sandy soils are usually characterized by poor species composition due to a small number of species adapted to this type of habitats. Yorkshire fog usually predominated under conditions of insufficient moisture as well as the lack of fertilization and improper use [Wyłupek 2008]. Similarly, red fescue often predominates in sward at the lack of fertilization [Kopeć 2000].

The impossibility of migration of meadow species diasporas is an additional factor preventing the appearance of new species. The lack of seeds is usually one of the major causes making it impossible for multi-species meadow communities to regenerate. In Holland [Bakker et al. 2002] even after 25 years of extensive use the migration of species of poor communities did not occur, in spite of their presence at a small distance. Smith et al. [2002] proved that a combination of cutting, grazing and additional sowing of desirable plant species is necessary for an increase in the species diversity of intensively utilized meadows. The experiment was located in areas where typically utilized meadows and pastures with rich species diversity, from where seeds of those species could migrate, do not exist anymore. Under such conditions, introduction of such species which would be adapted to the local habitat conditions should be taken into consideration. Such action is already applied in some European countries [Hopkins et al. 1995].

CONCLUSIONS

1. The most important factor affecting the species composition of meadow sward was utilization or its lack. The smallest number of species was found in the case of lack of cutting of cutting every second year.
2. The utilization systems used in the experiment diversified the biomass yield but they did not significantly affected the species composition of the sward. Diversification of species composition between the years was higher than that between utilization systems.
3. Under conditions of permeable and poor soils, fertilization with manure can have a favorable effect not only on yield but also on an increase in species diversity.
4. To increase the number of species, in the case of the lack of their occurrence in the neighborhood, additional sowing of species adapted to the local habitat conditions should be additionally applied.

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OCENA WPŁYWU RÓŻNYCH SPOSOBÓW EKSTENSYWNEGO UŻYTKOWANIA NA RÓŻNORODNOŚĆ GATUNKOWĄ UŻYTKÓW ZIELONYCH

Streszczenie. Zachowanie różnorodności biologicznej użytków zielonych wymaga ich odpowiedniego użytkowania. W wielu przypadkach, zwłaszcza na obszarach chronionych, zachowanie różnorodności gatunkowej staje się głównym zadaniem zabiegów uprawowych. Celem badań było porównanie wpływu kilku mało intensywnych sposobów użytkowania na kształtowanie się składu gatunkowego runi. Doświadczenie prowadzono w latach 2001-2007 w okolicach Krakowa (Bielany, 50°02’ N; 19°50’ E), na glebie piaszczystej o niskiej żyzności. Zastosowano cztery sposoby nawożenia. Ruń koszono w dwóch terminach – na początku czerwca i pod koniec lipca. Pomimo znacznego zwiększenia wysokości plonu pod wpływem nawożenia, nie stwierdzono istotnego statystycznie wpływu sposobu użytkowania na liczbę gatunków i współczynnik różnorodności Shannona-Wienera. Różnice w udziale najważniejszych gatunków (kostrzewy czerwonej, kłosówki wełnistej i krwawnika pospolitego) były większe pomiędzy poszczególnymi latami doświadczenia niż pomiędzy obiektami. Jedną z przyczyn braku wpływu różnych sposobów użytkowania na różnorodność gatunkową mógł być brak możliwości pojawienia się diaspor gatunków łąkowych z sąsiedztwa. W konkluzji stwierdzono, że dla odtwarzania wielogatunkowych zbiorowisk łąkowych niezbędne może być dosiewanie wybranych gatunków łąkowych.

Słowa kluczowe: kłosówka wełnista, kostrzewa czerwona, krwawnik pospolity, różnorodność gatunkowa, użytki zielone, użytkowanie ekstensywne

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