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SUMMARY – This work is concerned with the development of practical methods for restoration of species-rich meadows. One of potential methods for their restoration on arable lands is sowing regional seed mixtures. A field experiment was carried out in the years 2000-2003 on arable lands with the aim of evaluating the development of species-rich meadows, established by sowing different seed mixtures at two sowing rates (20 and 40 kg/ha). The results showed different development and a different role of individual components during four years of cultivation. Significant differences in herbage production and insignificant differences in characters between stands, established by a different sowing rate, are important from the viewpoint of the economy of meadow establishment.

Key words: Grassland biodiversity, restoration of species-rich meadows, regional seed mixtures, wild meadow species.

RESUME – *"Evaluation de différentes méthodes de restauration des prairies riches en espèces". L'objectif de cette étude est de développer des techniques pratiques permettant la restauration des prairies riches en espèces. Une des voies possibles est de resemer le sol arable par les mélanges régionaux de semences (MRS). Une expérience a été réalisée en 2000-2003 pour évaluer le développement des prairies riches en espèces qui ont été installées par semis du MRS (20 et 40 kg/ha). Les résultats montraient différents rôles de chaque constituant du mélange pendant quatre années de culture. L'importante variation de la production végétale et les différences non-significatives entre les prairies semées à différentes doses de semis sont des critères importants sur le plan économique permettant d'orienter la décision d'installation de ces prairies.*

Mots-clés : *Biodiversité des prairies, mélanges régionaux, plantes sauvages, restauration des prairies riches en espèces.*

Introduction

Historically, most of the meadows and grasslands of the temperate zones were formed, for long periods, by agricultural activity of man and adapted to traditional farming. At present, they mostly occupy a large area of farm land, forming an important part of the cultural landscape, managed by farmers. In the Czech Republic grasslands were managed quite intensively in the past decades because they were used as a source of fodder for a big number of farm animals.

With a dramatic decline in the number of livestock and changes in the intensity and structure of agricultural production, the productive role of meadows and pastures, especially in the agriculturally marginal areas, decreased. At present, however, their non-productive role in the landscape is strongly emphasized. Species-rich meadows are highly suitable to play this role, as they not only perform erosion-control, soil-conservation, filtration and landscape roles but are also characterized by plant and animal species richness (predominantly due to dicotyledonous plants flowering) for a large part of the vegetation period. They create a very pleasant aesthetic impression that is often sought by man. They are of crucial importance for a well-balanced landscape because they are the place where the natural nutrient cycling takes place. They can also be used in extensive animal farming. Permanent grassland has become an important source of plant genetic resources.

Species richness as a reflect of site conditions and the traditional farming system decreased significantly during the past decades, not only in our country but also in other countries such as, for example, England, Switzerland or France (Muller *et al.*, 1998; Nösberger and Kessler, 1997; Pywel *et al.*, 2002). The species richness of natural meadows was negatively affected not only by previous intensive management, but also by the real abandonment of agricultural farming.

One of the possible ways for supporting revitalization of species-rich plant communities is the sowing and over-sowing of seed mixtures containing wild species of grasses, legumes and other herbs related to the region of their origin (Jones and Hayes, 1999; Krautzer, 1996). The initial seed is obtained by collecting on natural species-rich meadows and used at first for the establishment of seed multiplication stands and, then after propagation for the restoration and establishment of species-rich meadows, important above all for their non-productive roles. The object of the study is becoming more and more important with the present changes in agriculture – the ongoing re-structuring of land resources is connected with a considerable increase in the area of newly sown grasslands and with their expected non-productive utilization. The aim of the study was to evaluate the effect of the sowing rate of different species-rich mixtures and different methods of grassland establishment on development and changes in botanical composition of the sown stands in a field trial.

Materials and methods

The location of the study was the experimental area of the Grassland Research Station at Zubří (355 m a.s.l.), characterized by average daily temperature of 7.6°C (13.6°C during the growing season), and annual precipitation of 903 mm (556 mm during the growing season).

The experiment (Table 1) was established on 6 June 2000, with a standard size of an experimental plot of 30 m^2, 4 replications in split-plot design, without fertilization. The canopy density, presence of individual plant species, dominance of species (Braun-Blanquet scale and cover percentage) and herbage productivity (green matter) over the years 2001-2003 were recorded.

Table 1. Experimental treatments

Mixture	Abbreviation	Method of sowing	Sowing rate (kg/ha)
Regional	R20	All the experimental plot	20
Regional	R40	All the experimental plot	40
Fallow + R20	F+R20	Strip R20 into the fallow	20
Fallow + R40	F+R40	Strip R40 into the fallow	40
Fallow, control plot	F	-	-
Commercial herb	H	All the experimental plot	10
Commercial meadow mixture	C20	All the experimental plot	20
Commercial meadow mixture	C40	All the experimental plot	40

Plant material:

(i) Regional mixture comprised 6 wild grasses (83% in the seed mixture), 4 legumes (7%) and 21 herbs (10%), near to natural stand composition, details in Table 2

(ii) Commercial herb mixture comprised 6 wild grasses (10% in the seed mixture), 4 legumes (16%) and 18 meadow herbs (74%)

(iii) Commercial meadow mixture comprised 6 varieties of 6 grasses, (86% in the seed mixture) and 2 clover species (14%)

Results

The effect of the winter period on the condition of the stands was evaluated in the early spring. Direct damage of plants, caused by low temperatures or snow mould was not observed in any treatment. There were suitable conditions for clover dominance in the first and second harvest year.

Vegetation observations included a phytosociological evaluation of the stands. Table 2 gives an average area proportion of agro-botanical groups in the stands and the number of species present in the plots in the fourth year of growing.

Table 2. Proportion of agro-botanical groups in stands (%) and the number of species (2003)

Treatment	Sowing rate (kg/ha)	Grasses		Legumes		Herbs		Overall stand density (%)
		%	No. of species	%	No. of species	%	No. of species	
Regional mixture	20	35	9	35	8	30	17	80
Regional mixture	40	35	8	35	8	30	15	79
Fallow (+ regional mixture 20)	(20)	49	12	39	4	12	15	80
Fallow (+ regional mixture 40)	(40)	52	10	32	6	16	18	80
Spontaneous fallow	-	58	11	32	4	10	18	79
Commercial herb mixture	10	24	8	36	5	40	16	82
Commercial meadow mixture	20	61	8	35	3	4	11	74
Commercial meadow mixture	40	66	7	31	2	3	8	71

The table shows consistent results with sowing rates of the regional mixture, both in the botanical composition and in the overall canopy density. This suggests a possibility of using a lower sowing rate in grassland establishment, without any adverse effect on the potential abundance of stands. The proportion of their herb component (30%) is important, as it is close to the optimal. A higher, but comparable proportion of herb species (40%) occurs only in the herb mixture which, however, contains a high proportion of herbs in the sown mixture (74%). The fallows, in general, are characterized by a low proportion of meadow herbs (10-16%) in favour of grasses. In the commercial meadow mixture the presence of meadow herbs is rare.

The initial proportion of the species in the regional mixture and the abundance of individual plant components during 3 harvesting years is given in Table 3. For simplification the relative proportion of species was calculated on a scale of 0 to 3. For comparison there is also an initial proportion of the species in the sowing rate. The best abundance of grasses over the 3 years was observed in *Anthoxanthum odoratum* (3); medium abundance in *Briza media* and *Bromus erectus* (2). *Festuca rupicola* and *Poa angustifolia,* after poor initial abundance (1), became dominant in the fourth year of growing (3 and 2, respectively).

All the legumes reached a good abundance (2) during all the experimental period, except *Onobrychis viciifolia*, which remained insignificant (0). The most widespread herb became *Jacea pratensis* (3). Good dominance was observed in a number of species, such as: *Dianthus carthusianorum*, *Galium verum*, *Leontodon hispidus*, *Leucanthemum corymbosum*, *Leucanthemum vulgare*, *Plantago lanceolata*, *Prunella laciniata* and *Silene vulgaris* (2). *Knautia kitaibelii*, *Primula veris*, *Ranunculus arvensis* and *Sanguisorba officinalis* were either not found at all or they completely disappeared (0).

Herbage productivity in all plots was evaluated in the late first cut (Fig. 1). The date for cutting was determined with the aim of preserving the floral species-rich appearance of stands in the long run and allowing the largest number of species to reach maturity, release seeds and spread naturally. The evaluation of herbage yield is necessary, both from the viewpoint of its possible utilization (forage) or its removal (maintenance and ecology of landscape).

The green matter production of regional and herb mixtures, in comparison with commercial mixtures, is significantly lower in the first and second harvest year ($t_{0,01}$ =16.076** and 10.097**, respectively). However, the difference in herbage production between low-productive stands and commercial meadow mixture decreased in the second harvest year. Nevertheless, the use of forage mixtures is unsuitable in areas where non-productive role of the future stand is expected.

Table 3. Composition of a regional mixture and abundance of components in the stand (3: very good; 2: good; 1: poor; 0: not found)

Species	% proportion in seed mixture	Abundance in the stand		
		2001	2002	2003
Grasses (6 species)	82.86			
Anthoxanthum odoratum	3.77	3	3	3
Briza media	3.77	2	1	2
Bromus erectus	47.10	2	2	2
Festuca rupicola	14.10	1	1	3
Koeleria pyramidata	4.70	1	1	1
Poa angustifolia	9.42	1	1	2
Legumes (4 species)	7.05			
Anthyllis vulneraria	0.28	2	2	2
Onobrychis viciifolia	4.70	1	0	0
Trifolium montanum	0.94	1	2	2
Trifolium rubens	1.41	2	2	2
Herbs (21 species)	10.09			
Betonica officinalis	0.47	0	1	1
Campanula glomerata	0.20	0	1	1
Centaurea scabiosa	0.94	2	1	1
Cirsium pannonicum	0.47	1	1	1
Dianthus carthusianorum	0.28	0	1	2
Galium verum	0.47	2	2	2
Helianthemum nummularium	0.28	1	1	1
Hypericum perforatum	0.38	2	2	1
Jacea pratensis	1.41	3	3	3
Knautia kitaibelii	0.28	0	0	0
Leontodon hispidus	0.47	2	2	2
Leucanthemum corymbosum	0.28	2	2	2
Leucanthemum vulgare	0.47	2	1	2
Plantago lanceolata	0.47	3	3	2
Primula veris	0.47	0	0	0
Prunella laciniata	0.47	2	2	2
Ranunculus arvensis	0.47	1	0	0
Salvia verticillata	0.47	2	1	1
Sanguisorba officinalis	0.20	1	0	0
Silene vulgaris	0.20	1	1	2
Tragopogon orientalis	0.66	2	1	1
Total	100.00			

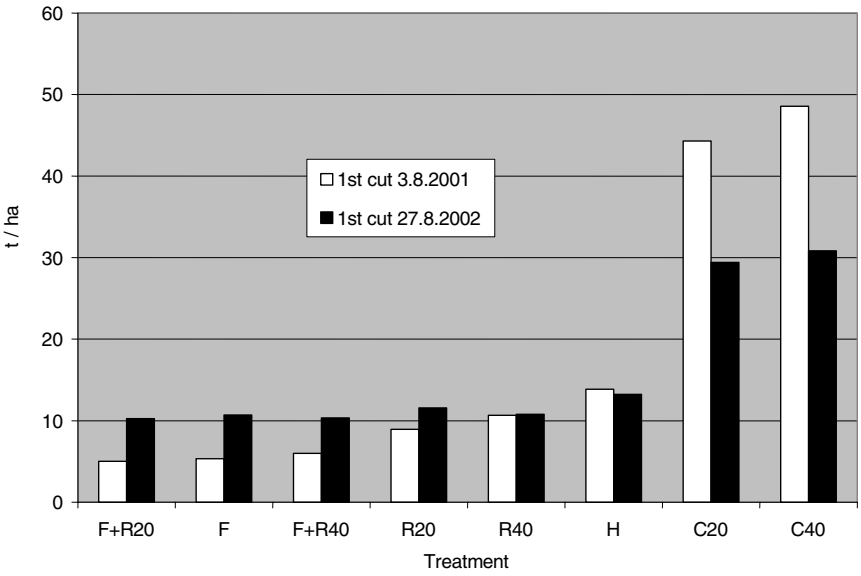

Fig. 1. Herbage production (t/ha)

Conclusions

Individual plant species show different abundance in restored species-rich grasslands. With regard to the potential future utilization of the newly established or restored stand, and other site conditions it is recommended to choose suitable components.

It was confirmed that stands established with a reduced sowing rate of a regional mixture (20 kg/ha) are fully comparable in their parameters with the double sowing rate. On the site with a very good seedbed preparation an expensive herb mixture may be sown at a lower sowing rate of 10 kg/ha. The regional seeds mixture, at the sowing rate of 20 kg/ha, was found as the most suitable to fulfil the above mentioned aims.

In the strip sowing of fallows individual species from the regional mixture spread slowly and thus allow weed species to develop, this must be taken into account especially on highly weed infested fields.

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