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USING A SEED MIX TO ESTABLISH NATIVE HAY MEADOW SPECIES IN ORNAMENTAL MEADOWS

ŁUKASZ ŁUCZAJ

Abstract. Species-rich meadows, although still common, are declining in Poland. For aesthetic and practical reasons it is becoming popular to plant similar 'wildflower meadows' in gardens. The performance of a seed mixture containing 18 flower species in the creation of new meadows was studied. Twenty-four newly created meadows were surveyed from 5 months to 2 years after sowing. *Leucanthemum vulgare* usually became dominant. Other successful species were *Achillea millefolium, Trifolium repens, T. pratense, Daucus carota, Lychnis flos-cuculi, Knautia arvensis, Lotus corniculatus, Centaurea phrygia, C. jacea, Tragopogon pratensis* and *Rumex acetosa*. The species that usually failed to establish were *Ranunculus acris, R. repens, Sanguisorba officinalis, Leontodon hispidus* and *Luzula campestris*. One of the meadows was divided into a grid of 2 × 2.5 m subplots and studied. Two site preparation methods were used: (1) November sowing on land cleared of weeds, with the application of glyphosphate (without ploughing), and (2) May sowing on land cleared with glyphosphate and ploughed in autumn, and then sprayed with glyphosphate in spring. Seeds were sown at varying densities (0, 1, 3, 9, 27 g/m^2). Sowing rates and land preparation methods had little effect on the number of established species, although sowing density of 3–9 g/m^2 and autumn sowing without ploughing produced the highest species richness. These are preliminary results which do not follow the fate of established species later in meadow succession, but they shed light on the potential for creating meadows from seed mixes.

Key words: grassland, *Arrhenatheretum*, species richness, restoration, sowing rate, competition

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INTRODUCTION

Both natural and semi-natural grasslands have suffered tremendous losses in the 20th century. Most natural grasslands have been ploughed up (e.g., Packard & Mutel 1997), whereas semi-natural grasslands have disappeared due to the intensification of agricultural practices or the cessation of grazing or mowing (Poschlod & Wallis de Vries 2002). To counteract these processes, efforts have recently been made to save the last remnants and to recreate destroyed grasslands. In North America, prairie restoration projects have become a cultural phenomenon (Packard & Mutel 1997). Grassland restoration has also been carried out in Western and Central Europe (Wells *et al.* 1989; Bretzel & Hitchmough 2000; Hitchmough 2000; Jongepierová *et al.* 2000). Scientists are not the only ones engaged in these endeavors. In the U.S.A., England and Germany this concept has infiltrated normal gardening practice, both in private gardens and in public areas (roundabouts, parks, motorways), and many seed companies offer a wide range of seed mixtures for this purpose (Brown 1989).

In spite of the variety of restoration projects, there are still few data documenting the results of these efforts and the performance of particular species. One of the factors most overlooked in these projects is the effect of sowing density on the species composition of the resulting meadows.

In Poland, up until recently the state of preservation of semi-natural grassland was much better than in Western Europe; thus conservationists concentrated on active protection of existing valuable remnants by mowing, grazing, or scrub removal, rather than creation of new grassland (Faliński 1972; Michalik 1985). However, the area of species-rich grassland is shrinking in Poland (e.g., Kucharski 1999). At the same time there is a trend toward growing native plant species. Stimulated by examples from other countries and by gar-

dening literature, people often think of creating meadows in their gardens (Łuczaj 1996). To meet this demand, in 1998, in the course of my work as a garden designer I started distributing seed mixtures composed of native grassland species to individuals interested in creating semi-natural grassland in their gardens (Łuczaj 2002). The potential plant community that develops on most mesic soils in Poland after long-term mowing once or twice a year is *Arrhenatheretum medioeuropaeum* meadow of the class *Molinio-Arrhenatheretea* (Matuszkiewicz 2005). In view of this, I composed a meadow mix in which most species are indicators or typical components of *Arrhenatheretum*; Poaceae species, important components of meadows, were excluded from the mix, however. This is because pilot experiments showed that adding grasses to such mixtures might strongly reduce the performance of the dicots; the public, the backers of the project, demanded highly colorful swards with the maximum possible density of showy flowers.

The aims of the study were to verify the success of the establishment of sown ornamental meadows, to compare the performance of particular meadow species and the effect of different sowing rates on the species composition, and to document the origins of the phenomenon of creating ornamental wild flower meadows in Poland.

Materials and methods

Seed mix

The studied meadows were created using a seed mix called 'Polska Łąka Kwietna,' which means the 'Polish flowery meadow.' I have been collecting the mix every year since 1999. Each year the number of species has changed, ranging from 12 to 25. In this paper the performance of the 18 most frequently used species was compared (Table 1). Often some annual species (*Papaver rhoeas, Vicia grandiflora* and *Anthemis arvensis*), giving color in the first year, were included as a small admixture. Most seeds were collected from semi-natural hay meadows and oldfields in the Krosno area in the Carpathian foothills. Seeds were harvested by hand between June and September, dried in a ventilated attic and stored up to 20 months (usually up to 12 months) in an unheated room. Exceptions were the seeds of *Trifolium* spp. and some of the seeds of *Lotus*, which were purchased in seed shops and originated from cultivation.

Table 1. Characteristics of the meadow mix harvested in 2000, sown in autumn 2000/spring 2001.

Species*	% germination (days)		% weight of seeds in the mix
	40	195	
Achillea millefolium	46	46	2
Centaurea jacea	12	32	2
Centaurea phrygia	54	54	2
Daucus carota	4	30	5
Galium verum	52	52	1
Knautia arvensis	4	14	5
Leontodon hispidus	60	60	15
Leucanthemum vulgare	84	84	17
Lotus corniculatus	48	48	2
Luzula campestris	60	60	1
Lychnis flos-cuculi	56	56	5
Papaver rhoeas	4	16	2
Ranunculus acris	46	46	15
Ranunculus repens	0	6	8
Rumex acetosa	46	46	5
Sanguisorba officinalis	16	16	5
Tragopogon pratensis	40	40	1
Trifolium pratense	70	70	3
Vicia grandiflora	14	20	1

* Nomenclature in this paper follows Mirek *et al.* (2002).

The meadows surveyed in this study were started from seeds collected in 1999–2002. The seeds for the experimental plot set up in 2000/2001 were harvested in 2000.

The proportion of species was intended to be equal, but it was biased by resource limitations, speed of collection, and aesthetic considerations (e.g., less attractive species such as *Achillea* or *Trifolium* were added only as a small admixture).

The germination rate of seeds collected in summer 2000 was assessed indoors. Fifty seeds of each species were surface-sown in pots (mixture of gardening compost and sand) in September 2000. The pots were regularly watered throughout the winter and kept in an unheated sunny room until spring.

Experimental plot

In 2000 I started an exhibition meadow for customers in Krosno. It was a wildflower meadow sown with different sowing densities. The different sowing densities were to make local variations in the appearance of the meadow. In the course of the work it became clear that this business and artistic endeavor could become the basis for a scientific study as well. However, the design of the plot (Fig. 1) was not random but regular and symmetrical; additionally, pseudo-replications occurred. This made statistical analyses practically impossible.

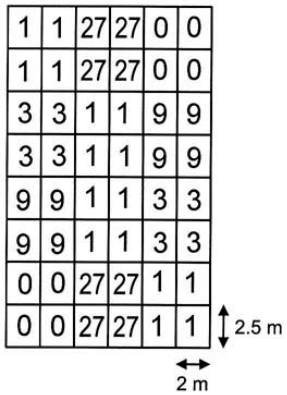

Fig. 1. The study plot in Krosno (Bieszczadzka St.): blocks sown in November 2000 and in May 2001. Numbers indicate sowing densities (g/m²).

The exhibition meadow (the experimental plot) is located in the town of Krosno (SE Poland) by Bieszczadzka Street, on a mid-mountain plain in the Polish Carpathians, on clay soil. Until 1999 the plot was used as an allotment for growing wheat, potatoes and ornamental flowers, ceaselessly cultivated from at least the beginning of the twentieth century. The land is completely flat. The plot is surrounded by a major street, a vegetable garden, and on two sides by a species-poor, recently mown oldfield.

The plot (Fig. 1) consisted of a 6 × 16 grid of 2 × 2.5 m subplots. In summer 2000 the plot was mown and the clippings cleared. In October 2000 it was sprayed with glyphosphate (10 l Roundup per ha) to remove the existing vegetation. Half of the plot was seeded on November 4th, and the other half was ploughed and harrowed in November, again sprayed with glyphosphate on May 9th, 2001, and seeded on May 15th.

The seeds were mixed with sand and hand-scattered on the soil without any further treatment. Four sowing densities were used (1, 3, 9 and 27 g/m²). Unsown control plots were also included. In total, each sowing density and the control part were represented by 16 subplots, except for the 1 g/m² density, represented by 32 subplots, double the number of the other densities. The difference in the number of plots did not affect the results, as only mean values per subplot were compared.

In July 2001, all the subplots were mown with a scythe. Clippings were left on the site. In each subplot, all the vascular plants were recorded in mid-June 2002, using a three-degree abundance scale (3 = above 50% cover; 2 = above 10%; 1 = less than 10%; 0 = absent).

Survey of meadows

Over 200 meadows were started using the described seed mix between 1998 and 2005, but I had access to only 20 meadows started in private or public gardens, including four experimental meadows set up in Krosno and nearby Rzepnik and Pietrusza Wola. All the meadows were visited at least once except for a meadow in Wodzisław, for which the inventory was made from detailed photos sent by its owners. Altogether, four meadows were surveyed in the Krosno area (SE Poland), three in other parts of SE Poland (Sanok, Kielce and Głogów Małopolski), eight in Warsaw and vicinity (Nadarzyn, Milanówek, Dziekanów Polski, Sobików, Krzaki Czaplinkowskie, Sierzchów), three in Silesia (Wodzisław Śląski and Pszczyna) and one in NE Poland (Pęchratka near Zambrów). Their area ranged from 50 to 5000 m². Most meadows were set up strictly according to my guidelines. The seeds were surface-sown at density of 1–2 g/m² on land cleared of weeds (by tilling and/or glyphosphate). The land had previously been used as lawns or for crops. The sowing season varied and was not recorded in detail for all the meadows. In four of the meadows, grass seeds were added to the mix at the owner's request. Four of the six meadows from the Warsaw area were occasionally watered. All the meadows were mown once or twice during summer.

Results

Seed germination

Most of the collected species germinated well without stratification, with over 40% germination (Table 1). None of the species completely failed to germinate, although we suspect that most *Ranunculus repens* seeds were not viable.

Study plot

Most of the sown species became established, but their success rates varied greatly (Table 2).

Table 2. Mean Abundance Index (scale 0 to 3) per 5 m² for the sown species.

Species	November sowing without ploughing	May sowing with ploughing	Sowing density (g/m²)					
			Unsown control	Average of all sown plots (1–27)	1	3	9	27
*Achillea millefolium**	1.03	0.95	0.81	0.99	0.97	1.00	1.06	0.94
Centaurea jacea	0.80	0.88	0	0.84	0.84	0.88	0.81	0.81
Centaurea phrygia	0.98	0.80	0.06	0.89	0.78	0.94	1.00	0.94
*Daucus carota**	0.30	0.58	0.13	0.44	0.31	0.56	0.56	0.44
Galium verum	0.73	0.13	0	0.43	0.31	0.44	0.44	0.63
Knautia arvensis	0.73	0.50	0.06	0.61	0.47	0.50	0.63	1.00
*Leontodon hispidus**	0.03	0.15	0.06	0.09	0.09	0	0.19	0.06
Leucanthemum vulgare	2.98	3.00	0.56	2.99	2.97	3.00	3.00	3.00
Lotus corniculatus	0.13	0.25	0	0.19	0.09	0.13	0.38	0.25
Luzula campestris	0.05	0	0	0.03	0.06	0	0	0
Lychnis flos-cuculi	1.00	1.23	0.06	1.11	1.19	1.31	1.06	0.81
Papaver rhoeas	0	0.13	0.56	0.06	0.06	0	0.19	0
*Ranunculus acris**	0.68	0.30	0.13	0.49	0.47	0.44	0.50	0.56
*Ranunculus repens**	0.65	0.58	1.31	0.61	0.69	0.81	0.69	0.19
*Rumex acetosa**	1.05	1.28	0.44	1.16	1.03	1.25	1.31	1.19
Sanguisorba officinalis	0.35	0.08	0	0.21	0.16	0.44	0.19	0.13
Tragopogon pratensis	0.05	0.03	0	0.04	0.03	0.06	0.06	0
*Trifolium pratense**	0.05	0.08	0	0.06	0	0	0.31	0
*Trifolium repens**	0	0.03	0.19	0.01	0	0	0.06	0
Vicia grandiflora	0	0.08	0	0.04	0	0	0.06	0.13

*species that occurred spontaneously in the vicinity of the study area (closer than 100 m) before sowing

The dominant species in all the subplots was *Leucanthemum*. Other species that showed good establishment were *Rumex, Lychnis, Achillea, Centaurea phrygia, C. jacea* and *Knautia*. The rest of the species were less successful. In addition, 69 spontaneous species were recorded in the plot (Table 3). The mean number of established species in the sown subplots (for all four sowing densities taken together) was slightly higher in the November-sown unploughed plots (9.2 ± 1.9 per 5 m²) than in the May-sown ploughed subplots (8.3 ± 1.9 species). The numbers of established species did not differ much between sowing densities; the highest richness in the November-sown part of the experiment was recorded for 3 g/m² sowing density, and in the May-sown part for 9 g/m² (Fig. 2).

The control plots were dominated by agricultural weeds. Some of the sown species were observed in the unsown control plots, mainly *Ranunculus repens* (commonest in the control part) and *Achillea millefolium*. Both these species grow wild around the study plot. Single individuals of other sown species that occurred in the control plots probably originated from seeds blown from other plots.

Overall species richness in the control plots was practically the same as in the sown plots (Fig. 3), which means that the number of spontaneously occurring species was larger in the control plots.

The success of most species seems to be little influenced by the sowing rate, except for *Knautia arvensis* and *Galium verum*, which were commonest in the most densely sown plots. All the sowing densities (1, 3, 9, 27 g/m²) produced aesthetically attractive multi-species swards, a feature important to landscape architects. For most species the abundance maxima were recorded for the 3 and 9 g/m² sowing rates.

Table 3. Mean Abundance Index (scale 0 to 3) per 5 m² for the 33 commonest unsown (spontaneously occurring) species (Mean Abundance Index = 10), and its sums for groups of species.

Species	November sowing without ploughing	May sowing with ploughing	Sowing density (g/m²)					
			Unsown control	Average of all sown plots (1–27)	1	3	9	27
Typical meadow species characteristic of hay meadow communities of the class *Molinio-Arrhenatheretea* or their frequent components								
Poaceae								
Poa pratensis	0.63	0.15	1.44	0.39	0.50	0.44	0.38	0.13
Holcus lanatus	0.33	0.40	0.36	0.25	0.38	0.44	0.50	0.50
Arrhenatherum elatius	0.15		0.08	0.13		0.13		
Anthoxanthum odoratum	0.03	0.08	0.05	0.06	0.06		0.06	0.06
Festuca pratensis		0.10	0.05	0.03	0.06	0.06	0.06	0.06
All Poaceae (9 species)	1.20	0.75	1.88	0.98	1.03	0.94	1.14	0.75
Non-Poaceae species								
Plantago lanceolata	0.33	0.08	0.13	0.20	0.25	0.13	0.19	0.19
Taraxacum officinale	0.05	0.35	0.19	0.20	0.16	0.25	0.25	0.19
Heracleum sphondylium	0.15		0.06	0.08	0.03		0.06	0.25
Stellaria palustris	0.05	0.05		0.05		0.19	0.06	
All non-Poaceae species (14)	0.75	0.63	0.70	0.68	0.50	0.57	0.87	1.00
All typical meadows species (23)	1.95	1.38	2.58	1.66	1.53	1.51	2.01	1.75
Ruderal and segetal species usually absent or rare in meadow communities								
Cirsium arvense	0.55	0.65	0.94	0.60	0.66	0.56	0.56	0.56
Equisetum arvense	0.50	0.58	0.69	0.54	0.53	0.56	0.50	0.56
Mentha arvensis	0.43	0.55	0.63	0.49	0.47	0.69	0.56	0.25
Tussilago farfara	0.68	0.28	0.31	0.48	0.53	0.69	0.44	0.19
Epilobium montanum	0.58	0.25	0.63	0.41	0.53	0.38	0.25	0.38
Convolvulus arvensis	0.40	0.33	0.31	0.36	0.31	0.44	0.38	0.38
Anthriscus sylvestris	0.35		0.38	0.18	0.09	0.13	0.06	0.50
Melandrium album	0.13	0.23		0.18	0.22	0.06	0.19	0.19
Urtica dioica	0.23	0.08	0.56	0.15	0.16	0.19	0.19	0.06
Artemisia vulgaris	0.23	0.05	0.13	0.14	0.13	0.31	0.13	
Galium aparine	0.20	0.05	0.25	0.13	0.13	0.25	0.06	0.06
Oxalis stricta	0.15	0.08	0.06	0.11	0.16	0.19		0.06
Vicia tetrasperma	0.20		0.06	0.10	0.13	0.06	0.19	
Stachys palustris	0.03	0.18	0.25	0.10	0.06	0.06	0.25	0.06
Agropyron repens	0.03	0.15	0.56	0.09	0.16		0.13	
Sonchus sp. div.	0.10	0.08	0.38	0.09	0.09	0.19		0.06
Myosotis arvensis	0.03	0.13		0.08	0.16		0.06	
Tanacetum vulgare	0.15		0.19	0.08	0.09	0.06	0.13	
Conyza canadensis	0.03	0.10	0.19	0.06	0.06	0.13	0.06	
Sinapis arvensis	0.03	0.08	0.81	0.05	0.06	0.06	0.06	
Ruderal and segetal species together (28)	5.00	3.83	7.96	4.44	4.76	5.01	4.20	3.37
Other species								
Potentilla anserina	0.53	0.63	0.56	0.58	0.59	0.56	0.56	0.56
Plantago major	0.50	0.18	0.31	0.34	0.41	0.50	0.19	0.19
Scrophularia nodosa	0.45		0.13	0.23	0.25	0.25	0.19	0.19
Rumex crispus	0.15	0.13	0.25	0.14	0.19		0.13	0.19
Other species together (18)	1.90	1.00	1.87	1.47	1.74	1.44	1.19	1.13

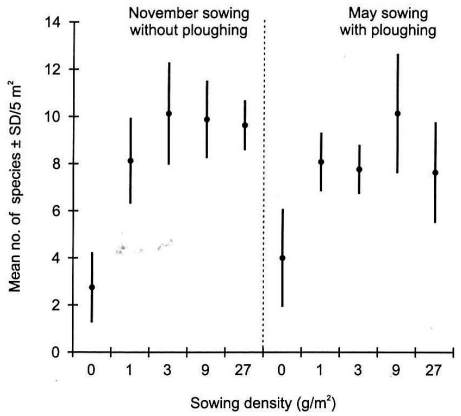

Fig. 2. Species richness of the sown species in the study plot.

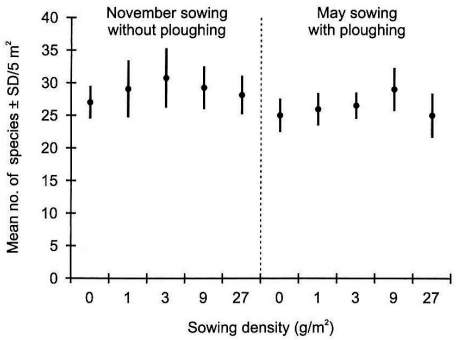

Fig. 3. Overall species richness in the study plot.

SURVEY OF MEADOWS

The studied species differed in their establishment success (Table 4). Two species, *Leucanthemum* (which usually dominated), and *Achillea millefolium*, became established in all created meadows. Other usually successful species were *Trifolium repens, T. pratense, Daucus carota, Lychnis flos-cuculi, Lotus corniculatus, Tragopogon pratensis, Knautia arvensis, Centaurea phrygia* and *Centaurea jacea.* The least successful species were *Ranunculus repens, Sanguisorba officinalis, Leontodon hispidus* and *Luzula campestris.*

At least half of the species included in the mix were sufficiently established both at sites cleared with glyphosphate and at those only ploughed.

DISCUSSION

This study showed that meadows can be created with a high success rate, but that the performance of sown species varies, with some species failing. The result is consistent with those of other grassland restoration projects, in which the dominance of *Leucanthemum vulgare* in newly created swards was also observed (Wells *et al.* 1989; Pakeman *et al.* 2002; Pywell *et al.* 2002). The domination of *L. vulgare* over other species is so strong that it might suppress other species, so its content in the mix should be lower than the average content of other species. *Trifolium pratense* and *T. repens* show similarly aggressive behavior in some soils and were excluded from the newest version of the mix, especially since they are ubiquitous in lawns and meadows. Some English seed companies even advertise their meadow mixes as *Trifolium*-free.

Various reasons for the weak establishment of some species can be suggested. *Leontodon hispidus* and *Luzula campestris* are low-growing species which may have failed to flourish because of the low frequency of mowing (once a year, in summer) in the studied meadows. The meadows were often started on rich soils; this may have decreased the species' competitiveness. *Sanguisorba officinalis* established only in the four wettest meadows. As it is a species of wetter meadows, its failure elsewhere may have been due to unsuitable habitat conditions. It may also need more time for establishment, as it has thick rhizomes whose development takes several years. The weak establishment of *Ranunculus* spp. may be due to the high moisture requirements of juvenile plants (*R. acris*), and low seed viability (*R. repens*).

In the Warsaw area, *Rumex acetosa* completely failed to establish in sandy soil, even though wild-growing individuals of this species were seen in the vicinity of the created meadows. It was observed, however, that the individuals on nearby sandy soil flowered in July; on the fresh meadows where the seeds were collected, the individuals

Table 4. Establishment success of meadow species recorded 5–24 months after sowing.

Species	No. of sown sites	% of sites where established	Proportion of the species in the mixture (% weight)	Remarks
Leucanthemum vulgare	20	100	10–20	quick establishment (often flowers in first year)
Achillea millefolium	20	100	1–5	
Trifolium repens	18	72	2–10	disappears from long swards
Trifolium pratense	17	71	2–10	sometimes tends to dominate
Daucus carota	16	63	2–8	
Lychnis flos-cuculi	20	60	4–15	failed in sandy soils unless watered
Knautia arvensis	20	60	3–20	should be sown densely as few seeds germinate
Lotus corniculatus	19	58	1–10	reliable in short swards
Centaurea phrygia	18	56	1–6	extremely reliable in clay soils, fails in sandy soils
Rumex acetosa	20	50	4–10 (the whole fruit)	fails on sandy soils
Tragopogon pratensis	17	47	1–4	
Ranunculus acris	18	44	10–25	high seedling mortality observed
Centaurea jacea	18	44	1–6	slow to flower (*ca* 3 years)
Galium verum	11	36	1–6	
Ranunculus repens	16	25	5–25	problems with seed viability
Sanguisorba officinalis	17	18	1–6	slow to mature (flowers after 3 years) but persistent
Leontodon hispidus	20	20	5–25	restricted to short swards
Luzula campestris	17	12	1–2	restricted to short swards

there flowered in June. These are probably two distinct subspecies, as *R. acetosa* is known for its variability (Rutkowski 1998). Large differences in the flowering periods of some other species were also noted during collection of seeds. *Knautia arvensis* and *Centaurea jacea* collected in moister *Arrhenatheretum* meadows and in *Molinietalia* meadows in Bratkówka flowered a month earlier (in May and July, respectively) than the same species collected in drier *Arrhenatheretum* and chalk grasslands in Rzepnik, Pietrusza Wola and the Dukla district. This emphasizes the importance not only of local origin of seeds, but also of matching the prospective sowing site to the ecotype. On the other hand, although disseminating seeds collected in the Carpathian foothills to other parts of Poland might seem ecologically inappropriate at first glance, one should bear in mind that the large hay trade of past centuries caused the unintentional spread of seeds fallen from hay loads across the country. The cessation of this trade is partly responsible for the current decline of grasslands; it reduced the recolonization opportunities for the species in question (Poschlod & Wallis de Vries 2002).

The results of this study suggest that the use of high sowing densities is neither harmful nor necessary in creating meadows. The density of *ca* 1 g/m² recommended by many seed companies proved sufficient. If the sown meadow seeds are valuable and the site is well prepared for sowing, even densities of 0.1–1 g/m² will probably give sufficient plant cover. The efficiency of the mix would be even higher if the proportion of species was more balanced and some large-seeded species such as *Tragopogon pratensis* were more strongly represented.

Observations made in the course of this study argue against using any grass nurse species, as advised by most authors (e.g., Mitchley *et al.* 1996; Pakeman *et al.* 2002), but this question needs a separate study.

Because meadows display long-term dynamics due to demographic changes in their plant populations (Falińska 1991), the surveyed sites should be revisited to determine longer-term establishment success. Preliminary observations three to four years after sowing at some of the meadows studied for this paper show that although most species persisted, slow changes in the proportions of species occurred. For example, good colonizers such as *Leucanthemum vulgare* and *Lychnis flos-cuculi* became less dominant at the expense of slower-growing species like *Sanguisorba officinalis, Ranunculus acris*, *Centaurea phrygia* and *C. jacea*, and spontaneous colonization by grasses was proceeding.

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