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Seminatural grassland management by long-term mowing of *Calamagrostis epigejos* in western Cserhát, Hungary

Abstract

Regeneration of seminatural grasslands are often threatened by the invasion of *Calamagrostis epigejos,* which can slow down or arrest secondary succession. Here we report the results of a 11-year mowing experiment designed to suppress the spread of *C. epigejos* in mid-successional grasslands in Hungary. The experimental design consisted of 16 permanent plots of 3x3 m. Half of the plots were mowed twice a year (in June and September), the other half was left as control. Vegetation was sampled in 2x2 m quadrats before mowing in each year between 2001-2011. The effects of mowing were tested using repeated–measure ANOVA and Tukey HSD for post-hoc tests. A significant decrease of *C. epigejos* appeared after two years of mowing. Species richness increased after four years, while diversity after eight years. By this time the target native species *Brachypodium pinnatum* had become dominant. Similar trends appeared in the control plots during spontaneous succession but at much slower rates. Our results suggest that *C. epigejos* disappears spontaneously in secondary grassland succession after ca. 40-50 years. However, mowing twice a year can speed up this process by opening a "colonization window" to the valuable target species. For successful control, mowing should be maintained for approximately eight years.

Management sekundärer Trockenrasen durch Langzeit-Mahd von *Calamagrostis epigejos* im westlichen Cserhát, Ungarn

Zusammenfassung

Die Regeneration von naturnahen Wiesen wird oft durch die Invasion von *Calamagrostis epigejos* gefährdet, das die sekundäre Sukzession verlangsamen oder zum Stillstand bringen kann. Hier berichten wir über die Ergebnisse eines 11-jährigen Mahd-Experimentes zur Unterdrückung der Ausbreitung von *C. epigejos* in Grasländern mittleren Sukzessionsstadiums im Westlichen Cserhát. Das experimentelle Design bestand aus 16 Dauerbeobachtungsflächen von 3 x 3 m. Die Hälfte der Parzellen wurde zweimal im Jahr (im Juni und September) gemäht, die andere Hälfte diente als Kontrolle. Die Vegetation wurde in jedem Jahr zwischen 2001 und 2011 in Quadraten von 2 x 2 m vor dem Mähen beprobt. Die Auswirkungen der Mahd wurden mittels wiederholter Varianzanalysen (ANOVA) und Tukey post hoc-Tests für HSD getestet. Ein signifikanter Rückgang von *Calamagrostis epigejos* konnte nach zwei Jahren Mahd festgestellt werden. Der Artenreichtum erhöhte sich nach 4 Jahren, die Diversität nach 8 Jahren. Zu diesem Zeitpunkt wurde die einheimische Zielart *Brachypodium pinnatum* dominant. Ähnliche Trends, allerdings deutlich langsamer verlaufend, traten in den Kontrollflächen während der spontanen Sukzession auf. Unsere Ergebnisse legen nahe, dass *Calamagrostis epigejos* nach etwa 40-50 Jahren in der sekundären Grasland-Sukzession von selbst verschwindet. Allerdings kann dieser Prozess durch zweimalige Mahd im Jahr beschleunigt werden, indem für die wertvollen Zielarten ein „Kolonisationsfenster" geöffnet wird. Für eine erfolgreiche Bekämpfung sollte das Mähen ca. 8 Jahre lang durchgeführt werden.

1 Introduction

The geomorphological and geographical features of Hungary are particularly suitable for agricultural usage. A large part of the country is typical agricultural landscape, including a substantial area under fruit cultivation and viticulture. Territorial composition of the plant culture, regional socio-economic changes and natural disasters can all have significant impacts on the proportions of cultivated, uncultivated, and abandoned land (Beck 2005).

Hungary is also characterized by the abandonment of cultivated areas. In these areas, secondary succession can start, resulting species rich plant communities in favorable cases. These communities can be similar to the original vegetation in aspects of species composition and structure, with high nature conservation value (Baráth 1963).

Throughout the long history of human land use in this region, changes in vegetation have occurred, the results of which can be important for ecological research and nature conservation. The reorganized vegetation units resulting from exploratory work in semi-natural grasslands can help in preservation and improvement. Because the loess covered areas were prioritized for agriculture due to extremely high fertility of the chernozem soils, there is little chance of preserving the remaining patches of original vegetation on these soils. Planting on the best soils started in the late Neolithic, and these areas have become almost entirely cultivated. Previously, loess vegetation was found in bands between private farms, but after agricultural collectivisation these areas disappeared too. Remaining small, non-cultivated grass fragments and ditches are often changed to narrow strips of secondary grasslands, and can often be degraded as well. For this reason, these grasslands and grassland fragments have high conservation value. These special habitats also preserve valuable relict and endemic plant species. Therefore, the protection and preservation of these grassland patches and fragments is an important task. It is also very important to develop a suitable nature conservation management plan. The main threat factors of grasslands are fragmentation, cultivation practices, changes in cultivation, overexploitation, land improvement, overgrazing, construction of linear elements, waste disposal and mining. The breaking up of grasslands, planting of forests, creation of vineyards and orchards or flooding of areas could mean total destruction of this habitat. During these processes, the remaining areas can be totally separated, resulting in the elimination of gene flow that can lead to genetic degradation. Regular moderate grazing and mowing can contribute to the maintenance of grassland. In the absence of mowing, an increase in weed and woody species cover can occur. In addition to mowing, scrub clearance should be carried out. Proper management can prevent dominance of invasive plant species. Appropriate grazing pressure can ensure continuous low disturbance, which is necessary to prevent tree growth and maintain high species diversity. Recent changes involve land use intensification and abandonment, and these processes are often accompanied by diversity loss in semi-natural habitats (Ryser et al. 1995, Fiala et al. 2003, Bartha 2007, Virágh et al. 2008). Grassland biodiversity is especially threatened by the collapse of extensive animal husbandry (Poschlod & Wallis de Vries 2002, Lindborg 2006). Decreasing species richness due to the aggressive expansion of grasses into grasslands has been reported from various parts of Europe (Rebele 1996, Sedláková & Fiala 2001, Huhta et al. 2001). *Calamagrostis epigejos* (L.) Roth is a tall perennial clonal grass (Prach & Pyšek 1994), and is a typical example of a plant species that spreads successfully to areas where former human management has been abandoned (Prach & Pyšek 2001). *C. epigejos* has a broad distribution range in Europe. It occurs in natural grasslands (Somodi et al 2008), in forests (Zhukovskaya & Ulanova 2006, Csontos 2010), in river floodplains (Fiala 2001, Gergely et al. 2001) and in ruderal assemblages (Prach 1987, Bartha 1992, Baasch et al. 2010a). It also appears in successional habitats developing after forest clearance or after the abandonment of agricultural fields (Csecserits & Rédei 2001, Bartha et al. 2010). This species can survive in dry, nutrient-poor environments, however, it is most successful in open, nutrient-rich, mesic habitats (Rebele 2000). *C. epigejos* is able to form monodominant patches and able to reduce species richness considerably (Somodi et al. 2008).

Frequent mowing was suggested as a potential management measure for repressing tall herbs or clonal grasses and for maintaining or improving grassland biodiversity (Huhta et al. 2001, Deák et al. 2007, Kramberger & Kaligaric 2008). Successful control of *C. epigejos* by mowing was reported from the first five years of vegetation succession on a species poor ruderal landfill site from Germany by Rebele & Lehmann (2001). However, there is no experience from other habitats, especially from secondary grasslands. The aim of this study was to find out how mowing treatment affects *Calamagrostis epigejos* and other species which co-occur in *C. epigejos* patches in secondary grassland developing in abandoned vineyards in a rural landscape.

Our specific questions were:

1. Is frequent mowing an effective management tool for controlling the spread of *C. epigejos* in secondary mid-successional grasslands?
2. How long a mowing period is necessary to reduce the cover of *C. epigejos* and to increase diversity?
3. How do active land management and long-term spontaneous succession interact at longer time-scales?

2 Materials and methods

Study site

The study site is located in the Cserhát hills, ca. 50 km from Budapest in Northern Hungary in a typical extensively managed rural landscape. The climate is temperate with mean annual precipitation of 520-590 mm and 8-10 °C mean annual temperature (Marosi & Somogyi 1991). The whole area is covered by a variable thickness of loess, which was formed during the ice age. From this loess blanket, parallel ridges emerge such as Bükkös hill (190 m above sea level) and Somló hill (202 m).

The study areas are situated on the north-east slope of the Somló hill, where the examined surface was 7 ha, and the north facing slope (3.3 ha) and the west facing slope (15 ha) of the Bükkös hill. Center coordinates are as follows:

Somló hill:	47° 47' 43.09" N, 19° 14' 23.37" E
Bükkös hill, North:	47° 45' 58.87" N, 19° 12' 51.57" E
Bükkös hill, West:	47° 45' 38.23" N, 19° 12' 47.53" E

The area was originally covered by the forest component of the Pannonian forest-steppe zone. According to old military maps (First Military Survey 1782) and other historical sources (Torma 1991), the area has been inhabited since the Bronze Age, and been mostly used as vineyards since the XVII century. For centuries, this hilly landscape was a mosaic of small vineyards, orchards and croplands with scattered patches of woods and steppes. Loess steppe fragments appeared on hilltops and ridges and wet meadows in the valleys. Land use has often changed due to wars and changing economic conditions. Therefore abandoned fields and the related secondary succession have a long history in the area and the species adapted to different successional stages are also part of the regional species pool.

Sampling

We carried out stratified random sampling. The shrub and *Robinia pseudoacacia* dominated patches were omitted, and patches with low cover of *C. epigejos* (less than 60%) were also disregarded. The remaining *C. epigejos* dominated patches were very abundant at the beginning of the study. They covered approximately 70% (*Calamagrostis* and *Calamagrostis – Brachypodium* type) of the total area of the research site. The diameter of these monodominant patches was larger than 25 m. We established eight pairs of 3 x 3 m permanent plots, positioned randomly along the north-eastern slope and arranged in a split-plots design of mown and control plots. The field experiment was conducted from 2001 to 2011, with mowing twice a year in June and in September of all years. Vegetation data were monitored in 2 x 2 m permanent quadrats placed in the middle of each 3 x 3 m plot, i.e. there was 1 m buffer zone between the paired (mown and control) quadrats (Fig. 2). Cover of each vascular species was estimated visually. The average minimal distance between the split-plots was 26 m, the maximal distance was 50 m.

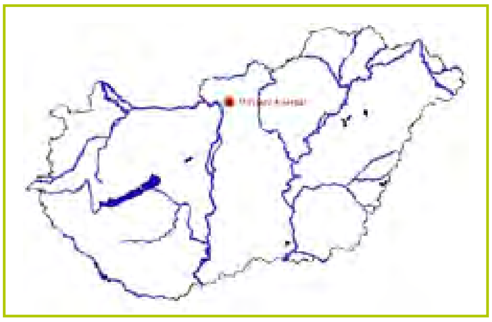


Fig. 1:
The study area in Northern Hungary.

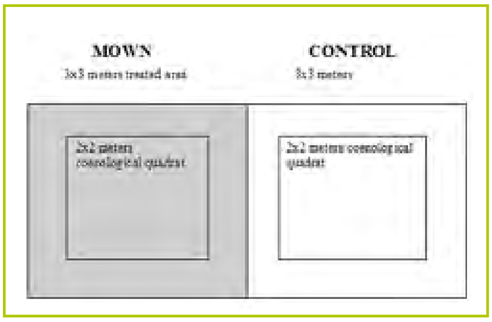


Fig. 2:
Mown and control plots according to the split plot methods.

Data analysis

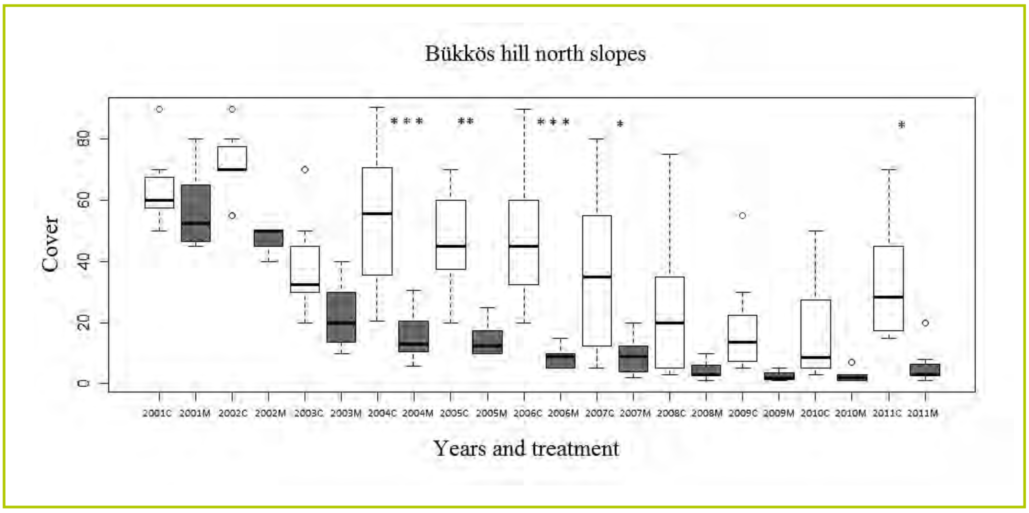
Total cover, species richness and the Shannon-diversity (Pielou 1975) was calculated. The effects of mowing were tested using repeated-measure analyses of variance (ANOVA). As *post-hoc* test, the Tukey Honest Significant Difference (HSD) with corrections (adjusted p-values for the multiple tests) was used. Data were analyzed using the R statistical program (R Development Core Team 2009).

Our experiment was performed in transitional vegetation with ongoing secondary succession. By mowing, we aim to promote the regeneration of this grassland to a target community (*Euphorbio pannonicae-Brachypodietum pinnati*) (Horváth 2010). Therefore, the success of the restoration measure should be evaluated not only by species richness and diversity but by evaluating the changing species composition.

3 Results

Mowing twice a year was effective to decrease the cover of *C. epigejos* (Fig. 3). The results of the repeated–measure analyses of variance showed that the treatment significantly affected the cover of *C. epigejos*. At the beginning of the experiment, *C. epigejos* was dominant in all plots with ca. 60% coverage. The average cover was 67% in the mown plots, and 69% in the control plots in the Somló hill.

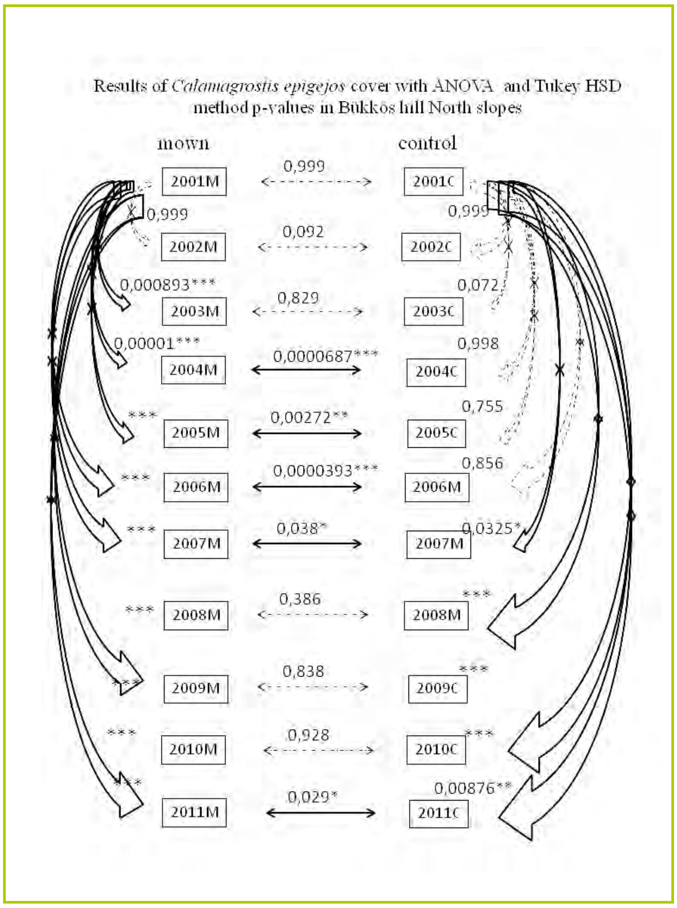
Fig. 3:
Change of cover of *C. epigejos* in the mown and control plots in Bükkös hill north slopes during the 2001-2011 period, M = mown plot (grayish boxes), C = control plot (open boxes). Significant differences between mown and control plots in the same year are marked by * (p<0.05).



On the Bükkös hill north facing slopes, this value was 62% and 63%, in the west facing slopes 72% and 71% respectively.

Due to mowing, its coverage decreased significantly after 2 years on the Bükkös hill west and north slopes, and after 3 years on the Somló hill. When compared to the starting year, a significant decrease of *C. epigejos* was detected also in the control plots. However, this spontaneous decrease appeared much later, after 6 or 7 years, and in one area there was no significant change (Fig. 4).

Fig. 4:
Change of cover of *C. epigejos* in the mown and control plots in Bükkös hill north slopes during the 2001-2011 period between mown and control plots and staring 2001 years and subsequent years. Significant differences are marked by * (p<0.05).



Repeated–measure ANOVA showed that species richness was significantly affected by mowing. Comparing the species richness between mown and control plots, significant differences were detected on the Somló hill in the 5th year, and only in the 10th year on the Bükkös hill. Comparing species richness of a particular year to the starting year of the experiment (2001), the first significant difference appeared after 5 years, and this difference was maintained during the subsequent years. There was no significant difference in the Shannon-diversity of the mown and control plots during the 11 years. Comparing Shannon-diversity of a particular year to the starting year of the experiment (2001), the first significant difference appeared after 2, 4 or 9 years, according to the different places (Fig. 5).

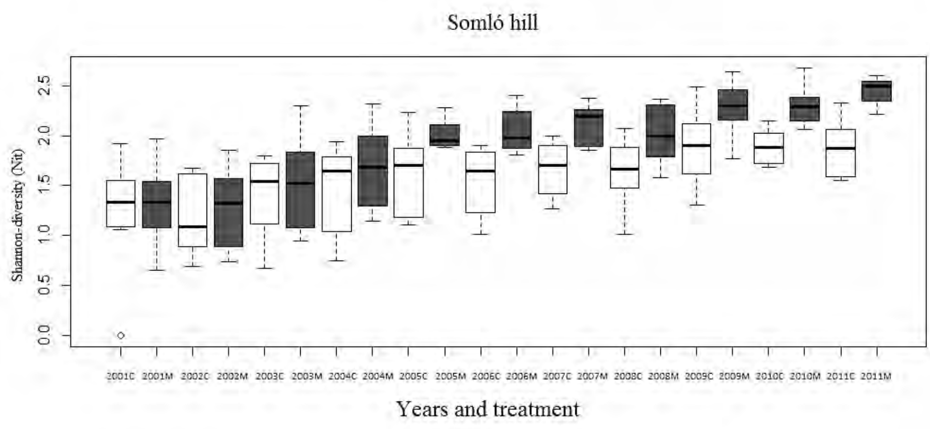


Fig. 5:
Change of Shannon-diversity in the mown and control plots in Somló hill during the 2001-2011 period, M = mown plot (grayish boxes), C = control plot (open boxes).

A general decrease was found in the cover of *C. epigejos* and a general increase in the cover of *Brachypodium pinnatum* on the Somló hill and *Festuca rupicola* on the Bükkös hill during the 11-year study.
The trend was similar between treatments, however, the speed of changes were greatly affected by mowing. In mown plots, *Brachypodium pinnatum* become dominant by the 5th year, and *C. epigejos* lost its dominance after 6 years. In control plots, *Brachypodium* become dominant 3 years later, only in the 8th year, and *C. epigejos* remained the 2nd most important species.

Beside the maintained cover of *C. epigejos*, "non-target species" with wide ecological range, remained also more important in the control plots. Overall comparison of the relative order of different species shows a similar pattern (Fig. 6).

Mown	2001.	2002.	2003.	2004.	2005.	2006.	2007.	2008.	2009.	2010.	2011.
1.	CEP	CEP	CEP	CEP	BRACH	BRACH	BRACH	BRACH	BRACH	DOR HERB	BRACH
2.	DOR HERB	BRACH	BRACH	BRACH	CEP	CEP	DOR HERB	DOR HERB	DOR HERB	BRACH	DOR HERB
3.	INU ENS	DOR HERB	VICIA	VICIA	DOR HERB	FEST RUP	CEP	CEP	Plantago	Plantago	FEST RUP
4.	Rubus	Rubus	DOR HERB	FEST RUP	VICIA	DOR HERB	Rubus	VICIA	CEP	GAL MOL	CEP
5.	BRACH	FEST RUP	FEST RUP	DOR HERB	FEST RUP	Rubus	FEST RUP	FEST RUP	ARRH ELA	CEP	ARRH ELA
6.	CENT SAD	INU ENS	INU ENS	INU ENS	Rubus	VICIA	Plantago	Coronilla	FEST RUP	VICIA	Plantago
7.	*Clematis*	VICIA	Rubus	Rubus	Plantago	PICRIS	PICRIS	Plantago	VICIA	Genista	GAL MOL
8.	CAREX H	Plantago	Plantago	Plantago	CENT MIN	Plantago	VICIA	Rubus	Rubus	ARRH ELA	Leontodon
9.	Coronilla	PICRIS	Stipa tirsa	Stipa tirsa	INU ENS	Carlina vulg	Campanula	PICRIS	Coronilla	Campanula	Campanula
10.	FEST RUP	CENT SAD	Astragalus	Astragalus	Stipa tirsa	GAL MOL	INU ENS	Campanula	INU ENS	Coronilla	Stipa tirsa
Control	**2001.**	**2002.**	**2003.**	**2004.**	**2005.**	**2006.**	**2007.**	**2008.**	**2009.**	**2010.**	**2011.**
1.	CEP	CEP	CEP	CEP	CEP	CEP	CEP	BRACH	CEP	BRACH	BRACH
2.	DOR HERB	BRACH	BRACH	BRACH	BRACH	BRACH	BRACH	CEP	BRACH	CEP	CEP
3.	Rubus	Rubus	Rubus	DOR HERB	DOR HERB	Rubus	DOR HERB	DOR HERB	DOR HERB	DOR HERB	DOR HERB
4.	INU ENS	DOR HERB	VICIA	VICIA	Rubus	INU ENS	Rubus	*Clematis*	Rubus	Rubus	Rubus
5.	Stipa tirsa	INU ENS	INU ENS	Rubus	INU ENS	DOR HERB	INU ENS	Rubus	INU ENS	AGRI EUP	GAL MOL
6.	BRACH	Plantago	DOR HERB	INU ENS	VICIA	FEST RUP	FEST RUP	INU ENS	*Clematis*	GAL MOL	Arrhenather
7.	AGRI EUP	AGRI EUP	FEST RUP	Stipa tirsa	FEST RUP	Stipa tirsa	VICIA	Coronilla	VICIA	VICIA	FEST RUP
8.	CENT SAD	FEST RUP	Plantago	FEST RUP	*Clematis*	VICIA	AGRI EUP	AGRI EUP	AGRI EUP	Coronilla	*Clematis*
9.	Plantago	Stipa tirsa	CENT	Plantago	Plantago	GAL MOL	Coronilla	Stipa tirsa	Plantago	INU ENS	***Cornus***
10.	GAL MOL	VICIA	*Clematis*	*Clematis*	Stipa tirsa	Plantago	Stipa tirsa	VICIA	Arrhenather	***Cornus***	INU ENS

Fig. 6:
The rank order of the first 10 most abundant species during the field study in Somló hill. Abbreviations are following: CEP: *Calamagrostis epigejos,* DOR HERB: *Dorycnium herbaceum*, INU ENS: *Inula ensifolia*, BRACH: *Brachypodium pinnatum*, FEST RUP: *Festuca rupicola*, AGRI EUP: *Agrimonia eupatoria*, CENT SADL: *Centaurea sadleriana*, GAL MOL: *Galium mollugo*, VICIA: *Vicia cracca*, CAREX H: *Carex halleriana*, PICRIS: *Picris hieracioides*, CENT MIN: *Centaurium minus*, Plantago: *Plantago media*, Clematis: *Clematis vitalba*, Coronilla: *Coronilla varia*, Arrhenather: *Arrhenaterum elatius*, Cornus: *Cornus sanguinea*, Genista: *Genista tinctoria*, Campanula: *Campanula glomerata*.

4 Discussion

In our experiment, mowing twice a year was effective in decreasing the cover of *C. epigejos*. However, the significant decrease appeared only in the 3rd year. A similar 2-year lag between the start of the mowing and the decrease of *C. epigejos* was reported by Rebele & Lehmann (2001) from a different habitat. The slow decrease can be attributed to the nutrient reserves accumulated in the rhizomes of this species (Fiala et al. 2003, Klimes & Klimesova 2002, Kavanova & Gloser 2005). *C. epigejos* lost high amount of its biomass due to the frequent cutting (Klimes & Klimesova 2002), but it takes several years to exhaust its stored nutrients. *C. epigejos* is known to colonize in the early stage of succession (Prach 1987, Bartha 1992, Bartha et al. 2008, Baasch et al. 2010b). Therefore, we expect that *C. epigejos* should have been present at least for 30 years in our site, and it might therefore have developed considerable nutrient reserves. Our results suggest that mowing twice a year is probably enough to exhaust the storage organs and to produce a negative nutrient budget for this species. Most studies found that mowing increased species richness in abandoned grasslands (Bobbink et al. 1987, Bobbink & Willems 1991, Fenner & Palmer 1998, Deák & Tóthmérész 2007). In our study, mowing also increased species richness and diversity in secondary mid-successional grasslands.

However, the response to the treatment was slow: a significant difference in species richness appeared after 5 years of mowing, and the increase in diversity appeared only after 8 years. *C. epigejos* is a tall grass with large amount of standing dead material and thick litter layer. It also has a large amount of belowground biomass. Therefore, it can be expected that it has strong competitive effects on other species. In a detailed study of the fine-scale species turnover in dense *C. epigejos* stands, decreased rate of local immigrations of other species was found, while the rate of local extinctions was the same as in the neighboring *Festuca rupicola* grassland (Somodi et al. 2008). Therefore, it can be hypothized that the negative effect of *C. epigejos* on diversity is based on the limitation of the establishment of other species. Mowing decreased the cover of *C. epigejos* and also the amount of the *C. epigejos* litter, i.e. mowing probably "switched off" the establishment limitation and it opened a "successional window" (Johnstone 1986, Bartha et al. 2003) for colonizing species. Our results show that after removing the limiting factors for species establishments, it took 3 additional years until significant number of new species was able to establish.

This result is in accordance with other studies reporting slow response of the vegetation composition to restoration measures (Stampfli & Zeiter 1999, Hellström et al. 2006). In most cases, the possible reason for the slow vegetation response is propagule limitation. In our case, the local species pool was relatively rich and most of the potential immigrant species were already present in the close neighborhood of the *C. epigejos* patches. Although these species were present a few meters from the experimental plots, it takes several years for them to disperse to the plots. The slow rate of diversity increase found in our study underlines the importance of fine-scale within-stand dispersal limitation and other fine-scale spatial constraints determining the rate and direction of vegetation dynamics (Bartha et al. 2004).

In our experiment, some of the significant differences between mown and control plots appeared after 2-3 years in the case of cover of *C. epigejos*, and 5-10 years for the increasing number of species, i.e. a shorter study would conclude that mowing was ineffective for increasing species richness in these successional grasslands. Our results suggest that restoration experiments should be designed for at least 8-10 years to get realistic results in this type of successional communities. Another advantage of long-term permanent plot experiments is that they enable us to study the interaction between restoration treatments and the spontaneous dynamics of the vegetation. To our knowledge, all previous studies about *C. epigejos* reported its spread (Aiken et al. 1989, ten Harkel & van der Meulen 1995, Rebele & Lehmann 2001, Sedláková & Fiala 2001, Holub 2002, Házi & Bartha 2002, Luoto et al. 2003, Stranská 2008, Somodi et al. 2008, Szirmai 2008), and no published study has found the reverse trend. In our experiment, we found a significant decrease of the cover of *C. epigejos* also in the control plots. Mowing resulted in a decrease of *C. epigejos* after 2 years, while a spontaneous decrease appeared after 6-7 years.

Studies analysing repeated vegetation surveys found either nearly linear increase in the area of patches dominated by *C. epigejos* (Somodi et al. 2010) or no trend, with fluctuation between 7 and 20% (Baasch et al. 2010a). In a large-scale survey of secondary grasslands developing on oldfields and on abandoned vineyards in Hungary (Bartha et al. 2010), *C. epigejos* was found to be abundant in the young successional stages but it is missing or less frequent in late successional grasslands. This result might imply that *C. epigejos* disappears spontaneously in secondary succession. However, this conclusion should be taken with caution, because the survey mentioned was based on a space for time substitution (Pickett 1989). Using space for time substitution, we assumed that all stands had the same history and the same landscape context. Contrary to this assumption, conditions changed considerably and the abandonment of grazing and mowing have become typical in recent decades (Poschlod & Wallis de Vries 2002, Lindborg 2006) parallel with the eutrophication of the environment (Dalton & Brand-Hardy 2003). In these changed environments, the *C. epigejos* might be advantaged, spread and achieve prolonged dominance.

Our study provides direct evidence that *Calamagrostis epigejos* can spontaneously decrease in secondary grassland succession. Further study is needed to understand the mechanism of these changes. In the control plots, where the cover of *C. epigejos* spontaneously decreased, species richness and the diversity also increased. This can be explained by the slow process and lag effects found also in the mown plots. In the control plots, a significant decrease of *C. epigejos* was detected after 6–7 years. Assuming a similar rate of colonization to the mown plots, we should wait another 2 years to detect an increase of species richness in these control plots.

While mowing is an effective method to reduce aggressive tall grasses and tall herbs, it may have a negative effect on other tall and broadleaved species that are components of the target community (Fenner & Palmer 1998, Bartha 2007). A further disadvantage of mowing is that it is expensive and hard to organize. Therefore, for the long term it is important to think about alternative restoration measures and conservation management. Prescribed burning cannot be an alternative because it increases the dominance of the *C. epigejos* (Hille & Goldammer 2007, Marozas et al. 2007). Therefore, we suggest that after a (ca. 8-year-long) period of mowing, grazing should be reintroduced to the area (Dostalek & Frantik 2008). Most people consider *C. epigejos* a dangerous invader, but this is not necessary true. In the early stage of the regeneration process it can have positive effects (for example by controlling soil erosion), and our results also suggest that its negative effects on diversity are not permanent.

Considering our specific questions, we conclude that frequent mowing is an effective management tool for controlling the spread of *C. epigejos* in secondary mid-successional grasslands. By mowing twice a year, it takes approximately 2 years to reduce the cover of *C. epigejos* and 2, 4 or 9 years to increase diversity. Our long-term study provided an unexpected result, i.e. the spontaneous decrease of *C. epigejos* in the control plots at much slower rates. Our results suggest that *C. epigejos* can disappear spontaneously in secondary grassland succession after ca. 40-50 years. Therefore, on a longer time-scale, spontaneous succession should be considered as a basis for active land management (Prach et al. 2001).

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