RESTORATION OF DRY GRASSLAND VEGETATION BY A COMBINATION OF SEED MIXTURE SOWING AND HAY TRANSFER

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Abstract. - Technical reclamation of grasslands is a powerful tool for biodiversity conservation in fragmented landscapes. Hay transfer and sowing seeds of local provenance are used most frequently to recover grassland vegetation in former croplands. The joint application of these two methods is rarely used, although it has the potential to gain a predictable and directed vegetation development with effective early weed suppression. Low diversity seed mixture sowing and hay transfer were applied in three former croplands (a former cereal, alfalfa and sunflower field) in Egyek Pusztakocs region, NE Hungary. We specifically asked the following questions: (i) Is a higher weed suppression rate feasible by the joint application of hay-transfer and seed sowing than by sowing only? (ii) Is the establishment of *Festuca* species favoured or suppressed by additional hay transfer? We found that the joint application of seed sowing and hay transfer significantly accelerated the development of perennial grassland vegetation and provided a higher rate of weed suppression in the first year and onwards than seed sowing only. A higher establishment rate was detected for perennial grasses including *Festuca* species in all plots with hay addition than with sowing only. Our results suggest that a combination of hay transfer and low diversity seed sowing may provide a cost-effective solution compared to the more costly high-density sowing, and if proper sources for high-diversity hay are available may replace high-diversity seed mixtures.

Keywords: Pannonic loess steppic grasslands, reclamation of former agricultural land, grassland restoration

Introduction

The major aims of grassland restoration actions are (i) to recover former species richness, (ii) to sow buffer zones around grassland fragments and (iii) to establish connections between isolated grassland stands (Walker et al., 2004). In grassland restoration it is important to recover native perennial grass cover to achieve the mentioned aims and restore grassland ecosystem functions (Conrad and Tischew, 2011; Kirmer et al., 2011). Recently, an increasing number of grassland restoration projects have been started and funded by the European Union (Cramer et al., 2008) which underlines the necessity of evidence-based results originating from well-designed case studies (Török et al., 2011).

Most frequently applied technical reclamation methods like seed sowing and plant material transfer are powerful tools for recovering grassland vegetation (Kiehl et al., 2010; Török et al., 2011). The joint application of these technical reclamation methods is rare, despite of the potential benefits combining a directed vegetation development (provided mainly by sowing) with effective early weed suppression (provided by the spread plant material cover). In our study we aimed at to follow the early grassland recovery influenced by the joint application of hay-transfer and seed sowing. We specifically asked the following questions: (i) Is a higher weed suppression rate feasible by the joint application of hay-transfer and seed sowing than by sowing only? (ii) Is the establishment of *Festuca* species favoured or suppressed by additional hay transfer?

Materials and methods

The study area is located in the "Egyek-Pusztakócsi mocsarak" grassland-marshland habitat-complex (Hortobágy National Park, East Hungary, N47°34', E20°55') in which area a large-scale grassland restoration was done between 2004 and 2008 (Török et al. 2010). In the present study, grassland restoration was done at three fields with a former crop of *Hordeum vulgare* (Field 1), *Helianthus annuus* (Field 2) and *Medicago sativa* (Field 3). Each field was sown with seeds of *Festuca pseudovina* (20 kg/ha). Avoiding field margins two randomly placed 15×15-m-sized plots were selected. One of the plots in addition to the seed sowing was covered by a 5-cm-thick hay layer. Hay originated from a species-poor native loess grassland characterised by the high cover of *Festuca rupicola* (up to 40-60% of total cover) and by the absence of *F. pseudovina*. Hay was harvested in June and spread in October after seed sowing in 2008. The separated transfer of the two *Festuca* species enabled us to distinguish sown (*F. pseudovina*) and hay transferred (*F. rupicola*) *Festuca* individuals.

All fields were mown once a year, mown plant material was carried away but hay covering was not subjected. Vegetation percentage cover scores were recorded in 1-m^2-sized subplots (four per plot) between 2009 and 2011. In every plot 20 aboveground biomass samples were collected each year near to the subplots. Biomass samples were dried (65°C, 24h), sorted into species, and measured with an accuracy of 0.01g. RM-GLM was calculated by SPSS 17.0 where 'time' as repeated measures factor, 'field and block design' as random factor and 'restoration method' (seed sowing and hay or seed sowing only) as fixed effect was included (Zar, 1999).

Results and discussion

Altogether 125 plant species including 56 weeds were detected during the three study years. In the first year short-lived weed species characterised the vegetation of every fields in high cover. Increasing cover of transferred perennial grasses (both by sowing and hay), and a decreasing cover of weeds was detected during the study regardless of field and restoration technique. The magnitude of weed suppression was influenced by the used restoration method and former crop. Lower cover scores of weeds were detected in plots with hay transfer. The mean cover scores of weeds was one third in year 3 of that detected in the first year, and only a few perennial weeds were detected with low cover. The biomass of weeds in line with the decrease of cover, decreased during the study, but the rate of weed suppression was affected by the former crop and the used restoration technique. The decrease of weed biomass was higher in plots with additional hay transfer. We found that the additional application of hay accelerated the development of perennial grassland vegetation and granted a higher rate of weed suppression already in year 1 than sowing only.

An improved weed suppression caused by the application of hay was feasible not only for weed cover, but also for species richness and in most fields for biomass of weeds (Fig 1). These results support Klimkowska et al. (2010) who assumed an improved weed suppression by application of hay. The reasons of improved weed suppression likely are that hay cover (i) decreases the irradiance of light and (ii) buffers fluctuations in temperature and water both functioning as common germination signals for gap strategist weeds (Foster and Gross, 1998) The spread hay also (iii) forms a physical barrier for weed establishment (Wedin and Tilman, 1993), and likely (iv) has an allelopathic effect on weed species (Ruprecht et al., 2010). The improved weed suppression was supported also by the high cover of *Festuca* species in most plots with hay transfer. This corresponds with the findings of another study of the authors in which a negative relationship was reported between the biomass of weeds and sown perennial grasses (Deák et al., 2011).

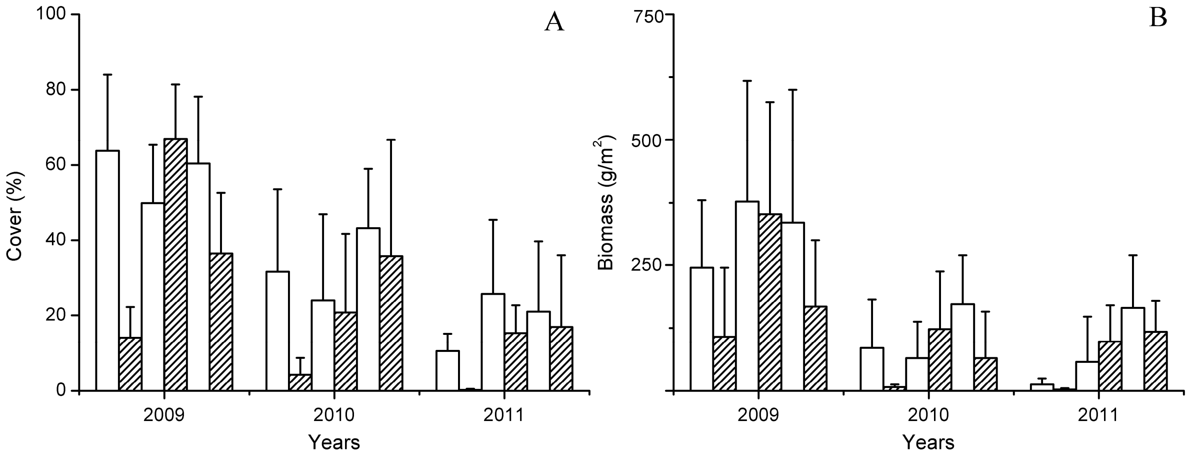

Figure 1 The cover and biomass change of weeds during the three years of study (Fields were shown as Field1 to Field 3 from left to the right, Notations: ☐ Sown only; ▨ Sowing+hay cover).

A rapid development from weed-dominated stages towards a perennial grass-dominated vegetation was observed in all fields (Fig 2). Species likely transferred with the applied hay were mostly grasses (*Festuca rupicola*, *Dactylis glomerata*, *Poa angustifolia*) and common Fabaceae species (*Medicago lupulina* and *Vicia grandiflora*). Higher cover scores of *Festuca* species were detected in plots with additional hay-transfer, and also the sown only *Festuca pseudovina* performed better. *Festuca rupicola* was established well in plots with hay transfer, but lower scores were also detected in a few plots sown only with *F. pseudovina* seeds. The biomass of *Festuca* species significantly increased during the three years of the study regardless of the field and restoration technique. The highest increase in the biomass of *Festuca* species was detected in most plots between year 1 and year 2 regardless of field and restoration measure. Litter scores decreased from year 1 to year 2 in all plots restored with additional hay transfer. In most plots restored by sowing only a slight increase of litter was detected between year 1 and year 2. The development of perennial grass cover was facilitated by the application of hay, which corresponds with findings of Kirmer et al. (2011) where seed-poor hay was used as a mulch layer in plots sown. A higher establishment of perennial grasses was found both in cover and biomass in all plots with hay than in plots with sowing only. In all fields in plots with hay transfer an increasing cover of *Festuca rupicola* and the facilitated establishment of the sown *Festuca pseudovina* were detected. Higher cover of the sown *Festuca pseudovina* was found in the first year in all plots treated by hay transfer than in plots sown only.

Figure 2 The vegetation of the plot treated by the joint application of seed sowing and hay transfer in Field 1 in 2011 (former crop: *Medicago sativa* (Photo byTamás Miglécz).

Similar results were reported by Kirmer et al. (2011) sowing *Festuca ovina* and *F. rubra* together with the application of mulching. Most likely, the additional application of hay provided more suitable water regime for the establishment of *Festuca pseudovina* and *F. rupicola* by soil surface covering in our study. Similar results were obtained by Kiehl and Pfadenhauer (2007) who found that the transferred hay provided safe sites for the germination of some target species in calcareous grasslands. We found that low-density sowing (a seed density of 20 kg/ha) facilitated the establishment of perennial grasses in both restoration measures without having any negative effects on the establishment of further hay-transferred species. This corresponds with the findings of Donath et al. (2007) where even at a higher load of seeds (50kg/ha) no negative effect of sown grasses was detected on the establishment and richness of hay transferred species.

Conclusions

Benefits of the joint use of sowing and hay-transfer are confirmed by the present study. With additional hay transfer a rapid suppression of weeds is possible even at low density sowing (up to 20kg/ha). With seed sowing only, a rapid weed suppression might be feasible at high loads of seeds (a density higher than 30kg/ha; Török et al., 2011). Low density sowing facilitates the rapid development of perennial grass cover and provides higher directionality of vegetation changes than hay transfer only. The combination of hay transfer and low-density and -diversity sowing may provide a cost-effective solution replacing the costly high-diversity and high density sowing if proper sources for high-diversity hay are available (Kiehl et al., 2010; Donáth et al., 2007). An indirect benefit of additional hay transfer is that the vital management by mowing in donor grasslands is done by the hay-harvest.

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