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Enhancing success in grassland restoration by adding regionally propagated target species

Annett Baasch[a,*], Karina Engst[a,b], Ralf Schmiede[a], Konstanze May[a], Sabine Tischew[a]

[a] *Anhalt University of Applied Sciences, Department for Nature Conservation and Landscape Planning, Strenzfelder Allee 28, D-06406 Bernburg, Germany*
[b] *Martin Luther University Halle-Wittenberg, Institute of Biology/Geobotany and Botanical Garden, Am Kirchtor 1, D-06108 Halle, Germany*

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ABSTRACT

The majority of grasslands of European interest are currently assessed as having an unfavorable conservation status. In order to fulfil the targets of the EU Biodiversity Strategy to 2020 effort to restore the diversity of species-poor grasslands are required. Besides the improvement of site conditions by management agreements the active introduction of target species by the transfer of on-site harvested plant material is recommended. Starting in 2009, we tested different methods to optimize species-introduction on example of a lowland hay meadow located in Saxony-Anhalt, Germany.

We set up an experiment to introduce target grassland species in prepared strips with four restoration variants: hay transfer, sowing of threshing material, and both methods combined with additional sowing of a regional seed mixture. We expected that (1) all applied methods lead to increasing number and cover of characteristic grassland species, (2) hay transfer is more successful than transfer of threshing material, (3) the highest number and cover of target species is reached after additional sowing of regional seed mixtures, and (4) species spread out from treated strips into the adjacent untreated grassland. We evaluated the success of the restoration measures yearly over a timeframe of six years.

The transfer of hay and the use of threshing material moderately increased the target species number. However, there were only slight differences concerning the establishment of target species between both introduction methods. In contrast, additional seeding of the regional seed mixture had a significant positive effect on the number of established target species. Many of the target species were solely established by additional seeding or were more frequently found on additionally seeded plots.

Species spread into the adjacent undisturbed grassland during a period of six years. The frequency of target species recorded in the adjacent undisturbed grassland was clearly related to the distance to treated strips, thus strips served as seed-source within the matrix of the existing low-diversity grassland. However, as high frequencies were mostly found only a few metres apart from strips, the spread of species across an existing low-diversity grassland have to be seen as long-term process and should be facilitated by appropriate management measures.

Depending on the availability of suitable donor sites and regionally propagated seed material, restoration practitioners and farmers can choose the most advantageous method of species introduction as all applied methods led to an increase in number and cover of characteristic grassland species compared to the untreated control. We recommend additional seeding especially if the species inventory of the donor sites is not entirely consistent with the target community, when abundances of specific target species on available donor sites in the surrounding area are too low, target species are difficult to harvest on-site because of a very early, respectively late, seed-setting time, or the donor grasslands are simply lacking some specific target species.

1. Introduction

Semi-natural grasslands shelter an important part of Europe's biodiversity (e.g. Dengler et al., 2014). Several grassland habitats identified as being of high conservation value are listed in Annex I of the EU Habitats Directive (92/43/ECC, Council of the European

* Corresponding author.
E-mail address: annett.baasch@hs-anhalt.de (A. Baasch).

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Union, 1992). However, 86% of grasslands of European interest are currently assessed as having an unfavorable conservation status (EEA, 2015). Especially in Central Europe semi-natural grasslands are threatened by both intensification and abandonment of land use (e.g. Gerstner et al., 2014; Joyce, 2014; Kleijn et al., 2009). Land-use changes caused considerable alterations in grassland communities' species composition, structure and functions and led to a continuous decrease of species-rich grassland habitats (EEA, 2015; see also e.g. Wesche et al., 2012). Therefore, besides maintaining still existing well-preserved grasslands, both the establishment of species-rich grasslands (for example on former arable land) and the restoration of the structure and composition of unfavourable assessed grasslands should have top priority.

In practice, attempts to enhance the diversity of species-poor grasslands are often limited to the reintroduction of extensive farming practices promoted by agri-environmental schemes. However, the effectiveness of local extensification measures is moderated by a variety of factors (e.g. Batáry et al., 2015; Kleijn et al., 2011; Whittingham, 2007). In consideration of the limited dispersal capacities of many grassland species, many studies highlighted the need of active species introductions due to the lack of appropriate seed sources of target species both in soil (i.e. depleted soil seed banks) and in the vicinity of restoration sites (e.g. Bossuyt and Honnay, 2008; Donath et al., 2003; Valkó et al., 2011). In addition, the limited availability of suitable micro-sites for germination within the grassland sward has to be overcome by mechanical disturbance of the soil surface prior to introducing target species (e.g. Bissels et al., 2006; Hofmann and Isselstein, 2004; Pywell et al., 2007; Schmiede et al., 2012).

Different techniques of species introduction (e.g. sowing regional seed mixtures, transfer of seed-containing plant material, topsoil removal and transfer) have already been developed and successfully applied in grassland restoration projects (for review see, Kiehl et al., 2010; Török et al., 2011). Most published studies focused on the establishment of species-rich grasslands either on former arable land or on marginal land, while studies using these species introduction techniques for enhancing the diversity of species-poor grasslands are still comparatively rare. Nevertheless, some studies showed that transferring seed-containing hay from species-rich donor sites can be an appropriate method to enhance plant biodiversity of species-poor grasslands provided that the existing sward has been adequately disturbed before (e.g. rotovation, ploughing, Edwards et al., 2007; Poschlod and Biewer, 2005; Schmiede et al., 2012). However, the efficiency of species transfer methods in existing species-poor grasslands is often stated to be lower compared with that on sites without established vegetation, e.g. tilled ex-arable fields or sites prepared by topsoil removal (Donath et al., 2007; Kiehl et al., 2010).

Hay transfer is particularly recommended for small-scale receptor sites at short distances from the donor site and when restoration can be done immediately after harvesting (Scotton et al., 2012). An alternative method is on-site threshing, i.e. the grass is cut and directly threshed through a combine-harvester on the grassland to extract the seed. The propagation material obtained can be dried and conserved. Thus, the use of threshed, dried and volume-reduced plant material is reasonable when high transport costs from remote donor sites require bulk reduction, when higher quantities for large-scale restoration are needed, or when there is a time lag between harvesting of seeds and site restoration (Kiehl et al., 2010; Scotton et al., 2012). However, harvesting efficiency (i.e. seed yield) has proved to be lower than for simple hay transfer (Scotton et al., 2012) that might make for a comparatively lower establishment of grassland species. Another alternative to simple plant material transfer is combining it with additional sowing to increase the diaspore pressure (see also Török et al., 2012), e.g. when abundances of specific target species on available donor sites in the surrounding area are too low, or the donor grasslands are simply lacking some specific target species. Because of the bad conservation status of many European grasslands (EEA, 2015), the acquisition of appropriate donor sites is particularly difficult in regions with overall derogated grasslands; but particularly in these regions grasslands require restoration measures.

Starting our project in 2009, we were not aware of any studies that have explicitly investigated the effect of these different methods of propagule transfer on the diversity and floristic resemblance of former species-poor grasslands. We set up an experiment in a species-poor lowland hay meadow to introduce target grassland species in prepared strips using a complete block design with four restoration variants: hay transfer, sowing of threshing material, and both methods combined with additional sowing of regional seed mixtures. We monitored the vegetation development over six years after the implementation of the restoration methods. Assuming that our observation period is sufficiently long, we hypothesized that (1) all applied methods of species introduction lead to an increasing number and cover of characteristic grassland species, (2) hay transfer is more successful than sowing of threshing material in restoring grassland diversity and composition, (3) the highest number and cover of target species is reached after additional sowing of regional seed mixtures, and that (4) species spread out from treated strips into the adjacent untreated grassland.

2. Materials and methods

2.1. Study site

The study site is part of the Natura 2000 area "Küchenholzgraben bei Zahna" located near the town Wittenberg in Saxony-Anhalt, Germany (51°52′52″N, 12°48′01″E, 78 m.a.s.l.). The climate is comparably dry and warm with a mean annual rainfall of 571 mm and a mean annual temperature of 9.4 °C (climatologic station: Wittenberg (WST), period: 1981–2010, DWD, 2016). The site is characterized by moderate fluctuations in soil moisture, but is not regularly flooded as it is typical for the large lowland hay meadows located at the floodplain edge of the riversystem Elbe. For our study we selected a species poor, grass dominated grassland (4.7 ha), which had been assessed as having the potential to be developed to the Natura 2000 habitat 6510 (Lowland hay meadow). The site was intensively used in former times; however extensive farming practices (hay-cutting regime, mowing once to twice a year with a first cut in June and the second in August, no fertilization) took place since 1994. For the on-site seed harvesting a suitable donor site was warranted in the vicinity of the restoration site. However, no available donor site in the 5 km surroundings of the restoration site exhibited all or most of the target species we intended to transfer. Finally, we selected a lowland hay meadow as donor site in close proximity to the restoration site (c. 3 km). The donor site was similar in abiotic site conditions (Appendix A), showed similar to the restoration site moderate fluctuations in soil moisture and exhibited some of the target species (e.g., *Silaum silaus*, *Sanguisorba officinalis*), the latter being also an important fodder plant for target butterflies (e.g. *Maculinea nausithous*). Other important target species on the donor site indicating transitions to communities of alluvial meadows were e.g. *Ranunculus auricomus*, *Achillea ptarmica* or *Allium angulosum* (Appendix B). After a first cut in June we regularly observed the seed maturation of target species during the second growth to choose the optimum time for the harvest of plant material (Scotton, 2016). On-site threshing was carried out on September 15th and cutting for hay transfer on September 27th, 2009.