SUCCESS OF FREQUENTLY APPLIED GRASSLAND RESTORATION TREATMENTS AND CONSEQUENCES FOR SUBSEQUENT MANAGEMENT

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Abstract: After up to nine years of development, restored sites not only lack target species, but also differ in species abundance order from reference sites. Seeding a non-site adapted, herb-poor mixture of non-local provenances was the most common treatment but the least successful. To improve success of future grassland restorations, seeding non-site adapted commercial mixtures of non-local provenances should be avoided in favour of site-adapted techniques using local plant material.

Keywords: mesophile grasslands, restoration practice, seed provenances; commercial seed mixtures, natural recovery

Introduction

Species-rich mesotrophic grasslands have a high nature conservation value and are considered as threatened habitats throughout Europe. Consequently they are identified as priority habitat types in corresponding guidelines and grassland restoration became increasingly important. In Germany, grassland restoration on arable land is area-wise the second most implemented compensation measure (Tischew et al 2010). Most of these measures were carried out using species-poor seed mixtures of non-local provenance that contain high amounts of stoloniferous grasses and are composed without taking local site conditions into account (Conrad 2007). Our study proved the assumption, often made by planners, that species composition of sites seeded with these mixtures become similar to regional types of mesotrophic grasslands over time and consequently restoration targets can be reached.

Materials and methods

The study area encompasses a 15 km wide corridor along the autobahn 14 (northwest corner: 51°89´N, 11°57´E; southeast corner: 51°51´N, 12°10´E) within the loess region between Magdeburg and Halle, Saxony-Anhalt. This region is largely homogeneous in terms of climate, soil characteristics, hydrological balance, land use, and adjacent habitats. Species-rich grasslands are scarce due to the dominance of large, intensively used arable fields.

Study sites have been intensively farmed for centuries before restoration measures were implemented. Sites were either sown (seed rate: 10 g/qm) or left to natural recovery. Mixtures used are similar in terms of species provenance (non-local provenance) but differ in whether or not they are adapted to the given soil conditions (non-site adapted vs. site adapted), as well as in species composition (herb-poor with forbs <5% vs. herb enriched with forbs >5%). We analyzed the following treatments: (1) NSA-HP: non site-adapted herb-poor mixture (n=15), (2) NSA-HE: non site-adapted herb-enriched mixture (n=19); (3) SA-HE: Site-adapted herb-enriched mixture (n=9), and (4) NAT: Natural recovery (n=5). Treatments were implemented in 1996 (NSA-HE), 1997 (NSA-HP, NAT), or 1999 (SA-HE). All sites were annually mown in June and September with subsequent removal of hay.

Species cover on restored grasslands was estimated yearly (1998 - 2001, additional data were recorded in 2005, Eckhardt (2007)) on quadratic permanent plots (plot size 25qm) from 1998 to 2001 using Barkman scale. To allow comparison of restored sites with vegetation of target grasslands, we used unpublished data of 21 reference plots on species-rich mesotrophic grasslands obtained by M. Conrad, S. Tischew, and H. Teubert. Reference plots were sampled once during the study period using the same method as for restored plots.

Numerical analyses were carried out using centres of cover classes of original Barkman scale (Tremp 2005). For treatments and reference sites, we calculated overall number of species per year as well as mean values for number and cover of six species groups (Figure 3). To assess overall restoration success, we calculated Soerenson´s and Motyka´s similarity of restored to reference plots. We used principal component analysis (PCA) to analyze treatment effects on species composition. To explore effects of treatments on univariate characteristics, we performed one-way repeated measures anova (between-subjects factor: treatments; repeated measures factor: age) and used Bonferroni procedure to test for within year differences among treatments. We checked normality and homogeneity of variance in anova with Lilliefors and Levene's tests. If assumptions were not met, data were log- or square-root transformed. We examined association between cover of *Festuca rubra* cultivars and number respectively cover of frequent and non-frequent target species by Spearman rank correlation (one-sided tests, frequent: present in >60% plane survey sheets of Saxony-Anhalt; non-frequent: otherwise).

Results and discussion

Neither species composition nor abundance order of restored plots had been similar to reference plots by the end of the study period. Both indices increased only slightly over time (Figure 1).

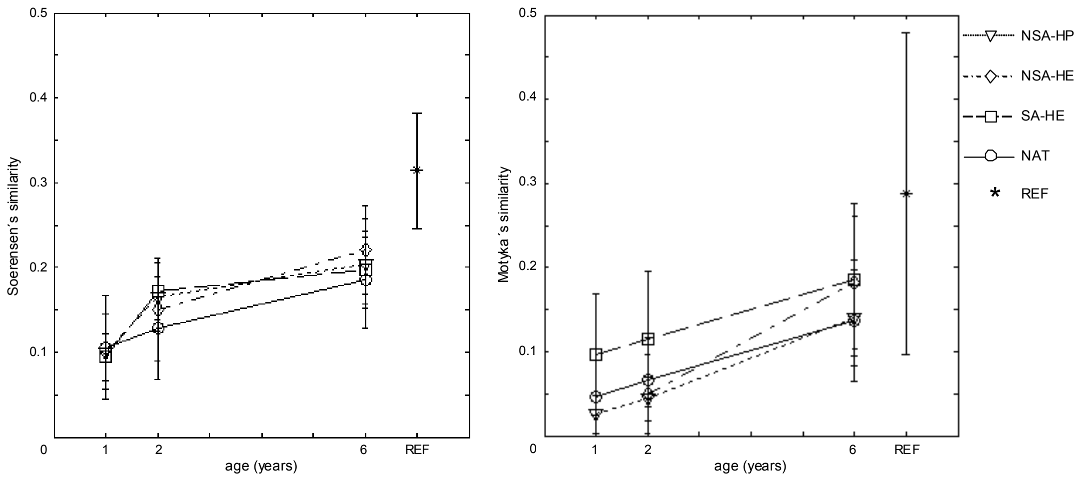

Figure 1. Means and standard error bars for Soerenson´s and Motyka´s similarity of restored to reference sites and average pairwise similarity of reference sites.

We found little dynamic in vegetation development for NSA-HP, whereas species composition of other treatments has changed over years (Figure 2 and 3). At NAT short-lived ruderal species and *Elytrigia repens* were replaced by perennial ruderal species as well as by target species that are frequent in adjacent habitats and immigrate spontaneously (Figure 3). Frequent gaps in plant cover seem to support species immigration and spread (see also Lepš et al. 2007). Seeded plots were dominated by sown species up from the beginning. Species that disappeared in NSA-HP (*Lolium perenne* and several short-lived species) were quickly replaced by dispersing *Festuca rubra* cultivars, perennial ruderal species and few target forbs. At sites sown with NSA-HE or SA-HE, perennial ruderal species increased as well (partly significantly), but by a fewer amount. Instead, more (sown) target species were able to spread successfully: For SA-HE these alterations came along with a noticeable decrease in cover of short-lived ruderal species. For NSA-HE decrease of *L. perenne* seems to support spread of target species by opening colonization windows (Zelnik et al. 2008). Nevertheless, short-lived species were always sparse on NSA-HE, indicating a dense sward with few immigration niches up from the beginning.

Altogether, NSA-HP results in the most homogeny, grass-dominated swards that differ significantly from most other treatments in terms of species number and cover. Herb-enriched mixtures lead to more diverse grasslands, but even these are dominated by seeded species. NAT is characterized by both grassland and ruderal species by the end of the investigation period and contain the highest number of spontaneously immigrated (grassland) species.

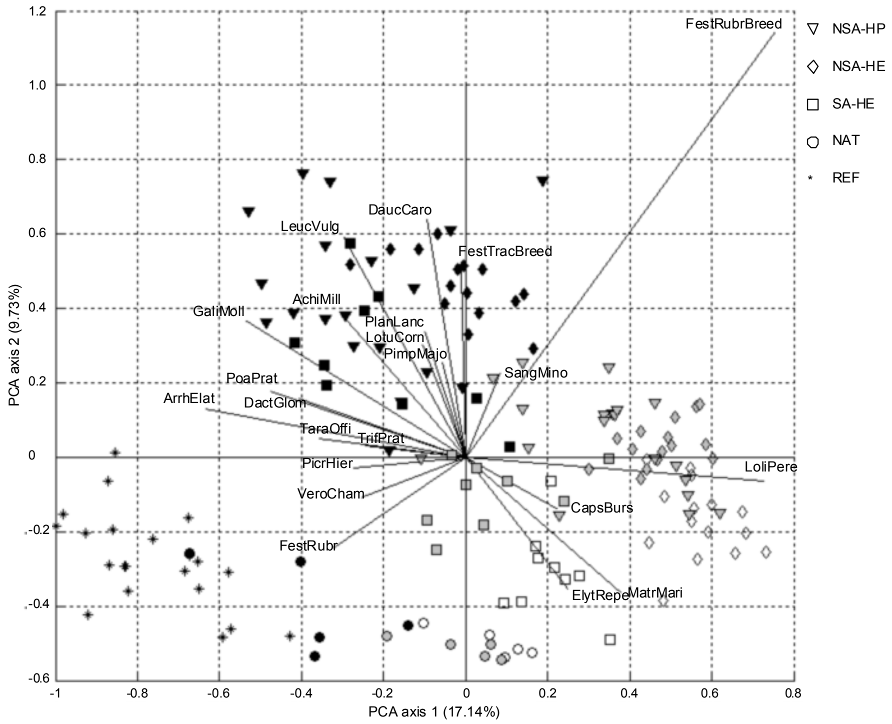

Figure 2. PCA biplot of species composition (open symbols: age 1, gray: age 2, black: age 6-9); data were log-transformed and centred by species; species scores were multiplied by two; only best fitting species are plotted.

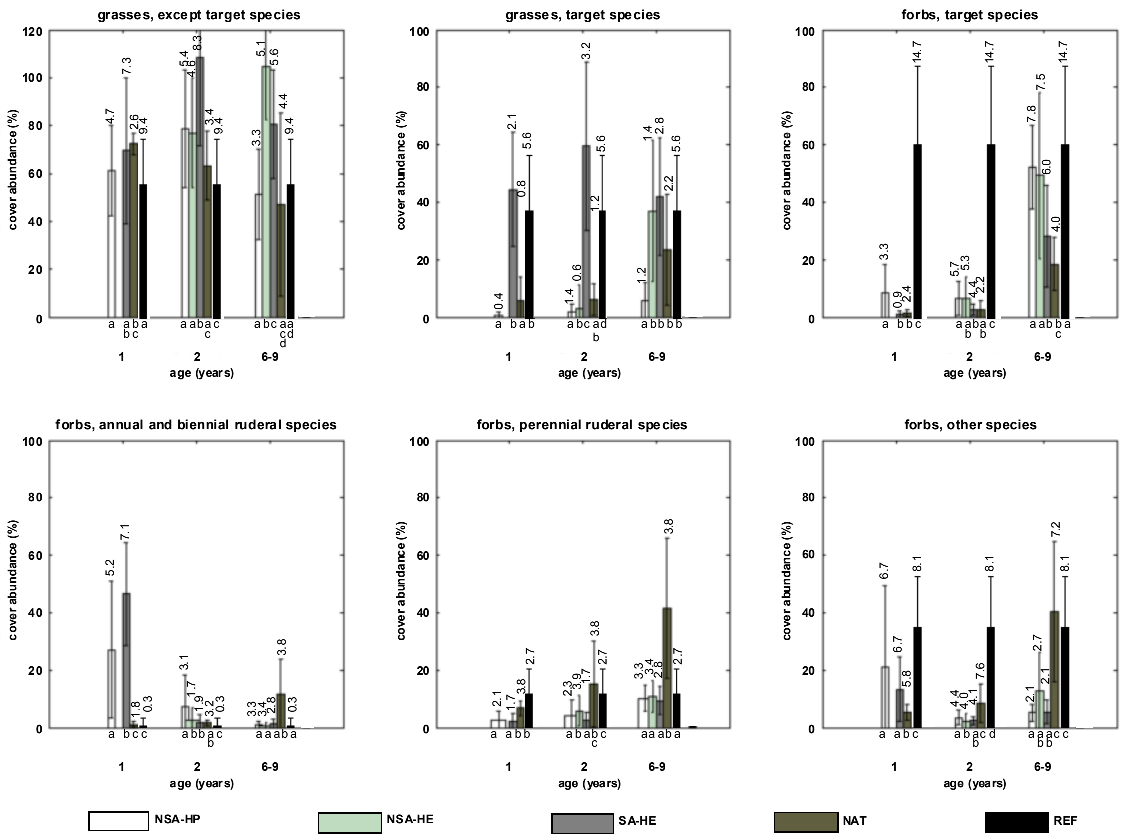

Figure 3. Means and standard error bars for mean cover, and mean number (above error bars) of six species groups; cover values with the same letter are not significantly different at the 0.005 level.

Compared to reference plots, low overall number of species and lack of target species is common to all restored plots. Even on plots with high cover of (seeded) target species, mean number is remarkably low. Comparisons of adjacent biotopes and restored sites confirmed results that state availability of propagules as limiting factor for successful grassland restoration (Pywell et al 2002). Therefore, sites seeded with herb-enriched mixtures that lack locally scarce target species will remain under saturated in the given species-poor surroundings if no additional species are introduced. Likewise, natural regenerated sites are likely to remain in their immature stage of development if no enrichment with selected target species takes place.

Apart from the availability of propagules, the presence of *Festuca rubra* cultivars seems to have a lasting effect on number and cover of target species as well. Over years, we observed an increasing cover of *Festuca rubra* cultivars accompanied by an accumulation of litter and decrease of establishment niches. We also found significant correlations of high cover of *Festuca rubra* cultivars and low number and cover of target species, except for frequent forbs. Correlation coefficients are always higher for non-frequent target species (Table 1).

Table 1. Spearman rank correlation coefficients (rs) and significance level (p) for correlation overall number and cover target species and cover *Festuca rubra* cultivars

Frequent target species				Less frequent target species			
	r_s	p for $r_s > 0$	p for $r_s < 0$		r_s	p for $r_s > 0$	p for $r_s < 0$
Number of grasses	-0.30	1.000	***<0.001***	Number of grasses	-0.48	1.000	***<0.001***
Cover of grasses	-0.19	0.997	***0.003***	Cover of grasses	-0.47	1.000	***<0.001***
Number of forbs	-0.05	0.744	0.256	Number of forbs	-0.27	1.000	***<0.001***
Cover of forbs	-0.05	0.760	0.241	Cover of forbs	-0.31	1.000	***<0.001***

Conclusions

To improve success of future grassland restorations, we strongly recommend avoiding, non-site adapted seed mixtures of non-local provenances. Particularly highly competitive species should never be used. Instead techniques that are considered as effective (e.g. hay mulch seed, seeding mixtures of local provenances) should be applied. Our results indicate that even natural recovery should be preferred over seeding mixtures of non-local provenances if not enough plant material of local provenances is available. However, in target species-poor areas, subsequent enrichment with selected target species is usually necessary to reach the restoration target

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