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Re-introduction of target species into degraded lowland hay meadows: How to manage the crucial first year?

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ABSTRACT

In grassland restoration, the first year after species re-introduction by sowing in former species poor grasslands is a crucial period for the restoration progress. Despite the preparation of the restoration site by ploughing or grubbing, the establishment window is usually open for only a short time period and germination as well as establishment of the sown target species is often hampered by dense vegetation stands and related low above-ground light-availability. However, concepts how to manage freshly sown sites differ widely. In the Elbe lowland plain (Saxony-Anhalt, Germany), we tested the effects of three different cutting treatments (cut once, twice, three times), three nitrogen fertilization treatments (120 kg N ha^{-1} yr^{-1}, 60 kg N ha^{-1} yr^{-1}, without fertilization), rolling versus no rolling as well as species-trait affiliation on the establishment of sown target species in a species-poor, grass-dominated hay meadow using a split-split-plot design. Eighteen target species were sown into ploughed and grubbed plots in autumn. In the following year, individuals of each sown species were counted in microplots before the first and after the last cutting date. The treatment effects as well as the species-trait affiliation were tested using generalized linear mixed models and principal component analysis.

Cutting three times significantly enhanced the number of established target species compared to cutting once showing the importance of biomass removal after species re-introduction into productive hay meadows. Compared to control plots, the 120 kg N ha^{-1} yr^{-1} fertilization led to a lower number of established target species as well as individuals, whereas moderate fertilization did not hamper the establishment success significantly. Rolling did not show a significant effect. In addition, species traits, such as the potential to build large hemirosettes close to the ground, specific leaf area, and species height are good predictors for the establishment success under the different treatments.

1. Introduction

Species-rich mesophilic grasslands are considered as endangered habitats throughout Europe, thus identified as an essential objective of general interest, for example, within Natura 2000 network (Council Directive 92/43/EEC). Major threats are intensification or conversion to arable land on the one hand and abandonment of management on the other hand (Bakker and Berendse, 1999; Dengler et al., 2014; Lindborg and Eriksson, 2004; Walker et al., 2004). Lowland hay meadows (habitat type 6510) have especially strongly declined since 1950 in Germany (Briemle et al., 1999), but also in other European counties (e.g. Öster et al., 2009b; Walker et al., 2004). Therefore, they are a focus of restoration projects throughout Europe (e.g. Lepš et al., 2007 for European grasslands, Germany: Buchwald et al., 2007; Conrad and Tischew, 2011; UK: Edwards et al., 2007; Pywell et al., 2002; Walker et al., 2004; Norway: Rydgren et al., 2010; Sweden: Öster et al., 2009b).

In grassland restoration, the first year after species introduction seems to be the most crucial period. Young seedlings are extremely sensitive to different biotic as well as abiotic factors resulting in a high loss rate (Fenner, 1987; Grubb, 1977). However, as shown by Öster et al. (2009b), a high first-year recruitment of sown species is very important for long-term establishment and therefore for the restoration outcome. It is thus a question how to manage this crucial first year to achieve high establishment rates of introduced species.

Particularly if a major part of farmed grassland is embedded into restoration schemes, restoration projects are often confronted with farmers demands. Because lowland hay meadows represent major forage sources for livestock feeding, farmers stipulate that the restoration sites are sufficiently productive and provide hay with a good forage quality already in the restoration phase. This

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would imply to fertilize restoration sites (mainly with nitrogen), cut them twice a year as well as roll them using large machinery, like under traditional grassland management practices. The question is, how would this affect the establishment of introduced target species? On the one hand many grassland restoration projects cut their restoration sites only once a year (Hölzel and Otte, 2003; Jongepierová et al., 2007; Török et al., 2010; van der Putten et al., 2000) or even refrain from cutting in the early restoration period (Nordbakken et al., 2010; Rydgren et al., 2010). A relatively low biomass production is given as one argument for this management (Hölzel and Otte, 2003). Other arguments may be the fear of increasing soil compactness by cutting with large machinery (Schäffer et al., 2007), which can reduce seedling establishment (Török et al., 2011) or the disturbances caused by cutting. On the other hand some restoration studies have demonstrated that frequent cutting already in the first year can have positive effects on seedling establishment (Hofmann and Isselstein, 2004; Lawson et al., 2004). In particular, on sites with high soil nutrient contents seedlings of less competitive species can be suppressed by an increase in aboveground biomass and therefore increased light limitation for understory species (Borer et al., 2014; Hautier et al., 2009). Thus, frequent cutting may be a useful measure to reduce negative competition effects particularly in the first crucial year of establishment and on more productive sites (Borer et al., 2014; Lawson et al., 2004). Furthermore, effects of fertilization on seedling establishment might also be different depending on the intensity of biomass removal, i.e. cutting time and frequency. Therefore, testing the effects of different mowing regimes in combination with different nitrogen fertilization treatments is highly relevant for restoration practice, but has rarely been tested (Foster et al., 2009; Jones and Hayes, 1999; Smith et al., 2003). Apart from cutting and fertilization, rolling represents a further common management measure in Europe particularly practiced on former fen sites which are currently used as hay meadows. Rolling is mostly practiced in spring for soil consolidation and frost crack closing. There is little knowledge on the effects of rolling on the establishment of freshly sown species (e.g. Harper et al., 1965). It is a question whether rolling damages seedlings and if the soil consolidation reduces suitable micro sites for seed germination.

In order to allow for generalization independent of site-specific species, species traits may be good predictors of establishment success under different management practices (Kahmen and Poschlod, 2008; Pywell et al., 2003). This approach was already successfully applied in several studies on grassland restoration (Andrade et al., 2014; Bissels et al., 2006; Öster et al., 2009a), but not yet used for a systematic analysis of integrated fertilization and cutting treatments.

In the present study, a field experiment was conducted to test under practice-oriented on-site conditions the effects of relevant management treatments in different combinations on the performance of target species in the crucial first year after sowing, especially on the number of target species and individuals as well as composition of target species. Since small-scale heterogeneity of soil parameters are supposed to be a common feature of large-scale restoration sites (Baer et al., 2004; Maestre et al., 2003), we also included selected soil parameters into our analysis. We hypothesized that (1) a high cutting frequency in the first year after sowing is important for the establishment success of the sown target species on productive grassland sites, (2) high nitrogen fertilization inhibits target species establishment but moderate nitrogen fertilization might not impede sown target species, and (3) rolling damages seedlings and thus reduces the establishment rate. We further hypothesized that (4) specific species traits are good predictors for species-specific establishment success under the different treatments.

2. Materials and methods

2.1. Study site

The study site was located in the Wulfener Bruch, which is part of a large lowland plain area of the Elbe River in the center of the German federal state of Saxony-Anhalt (11°58′ E, 51°50′ N) with an altitude of about 52 m above sea level. The area is characterized by a continental climate with mean annual precipitation of about 500 mm and mean annual air temperature of 9 °C (climatologic station: Köthen, period: 1961–1990, DWD, 2015).

The study site was a former half-bog, but, as in many other regions, the site was long-since drained and used as a hay meadow. The soils are gley soils with high organic matter content (14.3%) and therefore of high fertility. The total nitrogen content of the soil is about 0.7 ± 0.3%, available phosphorous (DL extraction) 11.6 ± 7.5 mg per 100 g soil and pH (0.01 M $CaCl_2$) of 6.5 ± 0.7. The high nutrient level is due to intensive use during the times of the former GDR (high fertilization with slurry, several cuts per year). After German reunification, the meadow has been extensively managed (no fertilization, only one cut per year). This former management resulted in species poor stands (18.3 species per 16 m^2) with a clear dominance of grasses and a dense vegetation structure, as well as high litter accumulation. The meadow can be characterized as a species-poor lowland hay meadow (Arrhenatherion, Habitats Directive code 6510) which shows some features of an alluvial meadow (Cnidion, code 6440).

2.2. Study design

We used a split-split-plot design with four blocks (replications) to study the effects of different treatments on the number and individuals as well as composition of target species in the first year after sowing (Table 1). The cutting treatment was the main treatment of each block, split by the fertilization treatment (split-plot treatment) which was additionally split by the rolling treatment (split-split-plot treatment). All possible combinations of these single treatments resulted in 18 different management treatments. For each of the 18 treatments and their replications a sample plot with a size of 4 m × 4 m was installed (altogether 72). Interspaces between sample plots were about 12 m to avoid reciprocal interference of the different fertilization treatments and to facilitate the use of large machinery for mowing and rolling. The cutting height was about 10 cm and cuttings were subsequently removed within one week. The nitrogen fertilizer (urea) was spread by hand only within the 4 m × 4 m sample plots. Rolling was carried out using machinery typically used by the local farmers for this purpose (manufacturer Güttler GmbH Germany, prismatic roll, width: 6 m, mass: about 3 t).

All treatments represent typical management practices for this region. Cutting once represents the management practiced over the last 20 years at the study site, but came under criticism because of the unsatisfactory results in terms of the loss of many typical meadow species, particularly low-competitive forbs. Cutting twice is nowadays applied at nature conservation grasslands and cutting three times is mostly practiced at sites where farmers need high amounts of forage for cattle. With regard to the fertilization treatments, no fertilizers are used at nature conservation grassland sites where the soil should be impoverished or where atmospheric nitrogen input is high, while 60 kg N ha^{-1} yr^{-1} are often used in already developed species-rich lowland hay meadows and alluvial meadows where atmospheric nitrogen input is low. Fertilization with 120 kg N ha^{-1} yr^{-1} is a typical practice if a high hay quality is required. Rolling is typically used at drained half-bog sites for soil consolidation and frost crack closing as explained above.

All sample plots were ploughed and grubbed before sowing at the beginning of September 2011 and were afterwards sown with

Table 1
Experimental treatments.

Code	Treatment and dates 2012
Cutting treatments	
Ct 1	One cut June 18th
Ct 2	First cut May 19th and second cut August 13th
Ct 3	First cut May 19th, second cut July 10th, and third cut September 3rd
Fertilization treatments	
N0	No fertilization
N60	Fertilization with 60 kg N ha^{-1} yr^{-1}
N120	Fertilization with 120 kg N ha^{-1} yr^{-1}
Rolling treatments	
−r	No rolling
+r	Rolled once in April

18 target species (Table 2, about 635 seeds m^{-2}, 1.11 g m^{-2}). Target species in this context are species characteristic for lowland hay meadows or alluvial meadows that were missing or present in only very low abundances on our study site. Most of the species are adapted to at least moderately nutrient-rich site conditions with Ellenberg *N*-values ≥4, with the exception of *Silaum silaus, Selinum carvifolia* and *Galium verum* (*N*-value = 3, Ellenberg et al., 1991). Seeds were of regional origin and propagation, as recommended for example by Kiehl et al. (2014) and Tischew et al. (2011). To facilitate an even sowing pattern seeds were mixed with soy meal.

2.3. Soil survey

In February/March 2012, soil samples were taken from every 4 m × 4 m sample plot. In each sample plot, we took eight single samples to a depth of 0–10 cm using a Pürckhauers soil core sampler and pooled them to a mixed sample. To analyze pH, 10 g dry soil of every sample was dissolved in 25 ml 0.01 M $CaCl_2$. The pH was measured after 30 min using a Mettler-Toledo pH-electrode (Mettler-Toledo, Gießen/Germany). The total N- and C-contents (%) of 200 mg dry soil were determined at 950 °C using a TruSpec CN-analyzer (manufacturer LECO, Mönchengladbach/Germany). To analyze the contents of plant-available phosphorus (mg P/100 g soil) and plant-available potassium (mg K/100 g soil) the double-lactate-digestion-method (DL-method) was applied. Phosphorous was then measured photometrically using a Spekol 1100 (manufacturer Carl Zeiss, Jena/Germany) and potassium was measured by atom absorption spectrometry (AES) with a ContrAA 700 (manufacturer Analytic Jena AG, Jena/Germany).

2.4. Vegetation survey

On each 4 m × 4 m sample plot one microplot of 0.5 m × 0.5 m size was installed for the vegetation surveys in the lower left corner. Before the first cut in 2012, individuals of sown species were counted on each of the 72 microplots (4 replicates for each of the 18 treatment). The counting was repeated after the third cut in autumn 2012.

2.5. Data analysis

We calculated generalized linear mixed models (GLMM) using IBM SPSS Statistics 22.0 (IBM Corporation, Chicago Illinois, USA) to test the effects of different management treatments on the establishment of target species. Cutting treatment, fertilization treatment and rolling treatment as well as the interactions of the management treatments (cutting*fertilization, cutting*rolling, fertilization*rolling) and the pH of the soil in spring 2012 (to consider differences in soil characteristics) were included as fixed factors. Block was the random factor. GLMM with a Poisson-distribution and identity-link were calculated for the two dependent variables, number of target species and number of target species individuals in autumn 2012. Furthermore GLMM with the spring data were analyzed to test for differences between the microplots before the different management treatments started. Post hoc tests were conducted to compare means by multiple tests after Bonferroni adjustment of 95% confidence intervals.

A principal component analysis (PCA) was performed to arrange the microplots according to the target species composition (species by sample matrix with the number of individuals of each target species per microplot). Information about the environment, i.e. management treatments (cutting, fertilization, rolling), soil chemical properties of the sample plots (compare Section 2.3) and selected species traits (compare Table 2) was used for post hoc correlation analyses as an interpretative tool to explain this arrangement. With respect to species traits the number of target species individuals with heavy seeds (TSW ≥ 2 g), large specific leaf area (SLA > 20 mm^2 mg^{-1}), large potential height (PH > 100 cm) and the ability to form large hemirosettes (HR) were used. The analyses were performed using PC-ORD 6.0 (McCune and Mefford, 2011).

Table 2
Sown target species with codes later used in results, sown quantities, and selected species traits: TSW = thousand-seed weight (specific for sown seeds), SLA = specific leaf area (LEDA Traitbase; Kleyer et al., 2008; na = not available), PH = potential height (Jäger and Rothmaler, 2011), large HR = large hemirosette close to the ground (BIOLFLOR; Klotz et al., 2002 and own on-site observations, + = yes, − = no).

Code	Plant species	Seed mixture		Plant traits used in analysis			
		seeds m^{-2}	g m^{-2}	TSW [g]	SLA [mm^2 mg^{-1}]	PH [m]	large HR
Cpa	*Campanula patula*	100	0.004	0.04	34.89	0.6	–
Cpr	*Cardamine pratensis*	100	0.057	0.57	25.13	0.6	–
Cca	*Carum carvi*	20	0.060	3.00	24.78	0.8	–
Cja	*Centaurea jacea*	20	0.042	2.10	18.31	0.6	+
Col	*Cirsium oleraceum*	20	0.050	2.50	25.74	1.5	+
Cbi	*Crepis biennis*	15	0.012	0.80	na	1.2	+
Dca	*Daucus carota*	50	0.050	1.00	21.70	1.0	+
Gal	*Galium album*	30	0.018	0.60	24.09	1.0	–
Gve	*Galium verum*	20	0.010	0.50	18.39	0.7	–
Gpr	*Geranium pratense*	20	0.120	6.00	20.00	0.6	+
Kar	*Knautia arvensis*	10	0.040	4.00	18.72	0.8	+
Lpr	*Lathyrus pratensis*	10	0.110	11.00	26.21	1.0	–
Pma	*Pimpinella major*	30	0.051	1.70	13.25	1.0	–
Rac	*Rumex acetosa*	20	0.011	0.55	23.08	1.0	–
Sof	*Sanguisorba officinalis*	50	0.100	2.00	15.06	1.5	+
Sca	*Selinum carvifolia*	50	0.050	1.00	17.98	0.9	–
Ssi	*Silaum silaus*	30	0.075	2.50	na	1.0	–
Tpr	*Tragopogon pratensis*	20	0.140	7.00	na	0.6	–

3. Results

3.1. Species establishment

By autumn 2012, 17 of 18 sown species were established on the study site. But, all 18 target species could be detected at least once at the first and/or the second counting on one of the microplots. On average 4.5 ± 2.8% of sown seeds m^{-2} germinated and established individuals in autumn 2012.

3.2. Effects of management on number of target species and individuals

In spring 2012, before management started, no significant differences in the number of established sown target species as well as the number of established individuals of target species between the different treatments were observed, which indicates a homogeneous initial state. On average, 3.4 target species and 5.6 individuals were established per microplot in spring 2012.

In autumn 2012, after management was finished, the number of established target species and individuals differed significantly between the different cutting and fertilization treatments (Table 3). Target species benefited from frequent cutting. The numbers of established sown target species and individuals were significantly higher on microplots cut three times compared to microplots cut only once (Fig. 1). In addition, even microplots cut twice showed significantly lower numbers of established target species individuals compared to microplots cut three times.

Nitrogen fertilization with 120 kg N ha^{-1} yr^{-1} led to both a significantly lower number of established sown target species as well as individuals compared to unfertilized microplots (Fig. 1). In contrast, microplots fertilized with 60 kg N ha^{-1} yr^{-1} did not have significantly lower numbers of established sown target species and individuals compared to unfertilized microplots. Moreover, the number of target species individuals on microplots fertilized with 60 kg N ha^{-1} $yr^{-1}$was significantly higher than on microplots fertilized with 120 kg N ha^{-1} yr^{-1}.

Rolling as well as pH had no significant effect on target species establishment (Table 3). However we found a significant interaction of fertilization and cutting on the number of target species individuals. Furthermore, the interaction of fertilization and rolling also significantly affected both the numbers of established target species and individuals.

3.3. Effects of management on species composition and species traits

The PCA confirms the negative effect of the high fertilization treatment with 120 kg N ha^{-1} yr^{-1} superposing all other effects (Fig. 2). The largest distance exists between the centroids of the Ct1_N120 treatment (lowest biomass removal + highest nitrogen input) and the Ct3_N0 treatment (highest biomass removal + lowest nitrogen input).

In post hoc correlation analysis none of the soil chemical parameters but three of four species traits were correlated with PCA-axis. Species which are able to build large hemirosettes close to the ground, like *Centaurea jacea*, *Daucus carota* and *Geranium pratense*, profit from no or only moderate fertilization and can cope with frequent cutting. On the other hand, species which have a high specific leaf area and/or which can potentially reach a height of at least 1 m, like *Galium album*, are not restricted to specific management treatments.

4. Discussion

In support of hypothesis 1, we found that a high cutting frequency (cutting three times) in the first year after sowing was important for the establishment success of the sown target species. This is in accordance with other studies (for example Hofmann and Isselstein, 2004; Lawson et al., 2004). The absence of a shading canopy in frequently cut plots is probably the main reason for this result (Isselstein et al., 2002), because competition for light is one decisive factor for the formation of plant species assemblages and affects the species richness of plant communities (Dybzinski and Tilman, 2007; Harpole and Tilman, 2007; Hautier et al., 2009). Thus, canopy removal decreases competition (Borer et al., 2014). The advantages of suitable initial site conditions for the survival rates of introduced endemic species, for instance lower competition with other plant species, were also shown by Colas et al. (2008). Furthermore, litter reduction as an effect of frequent cutting maintains gaps for seedling establishment (Török et al., 2011) and may thus have increased the number of established target species and individuals in the present study. The benefits of frequent cutting, especially in decreasing competition for light and litter accumulation, obviously outbalanced potential threats such as mechanical destruction in the course of cutting.

However, other studies also achieved good results with only one cut in the first year indicating the importance of initial site conditions. For example, if sites formerly used as arable land have been restored (for example Andrade et al., 2014; Hölzel, 2005; Török et al., 2012), competition by grasses might be less important than on former species poor grasslands dominated by competitive grasses. The presence of more short lived species on ex-arable land promotes the establishment of target species whilst grasses on former species poor grasslands might outcompete target species (Donath et al., 2007). Further reasons for good results with only one cut in the first year might be the different nutrient conditions of restoration sites. In many cases, ex-arable sites have low nitrogen contents (Gough and Marrs, 1990), which reduces competition even if phosphorous and potassium supplies are high (Pywell et al., 2002). Furthermore, topsoil removal as a site preparation treatment for restoration measures can also reduce the productivity of the restoration site to such an extent that biomass production, and therefore competition, is very low. In such cases, the cutting treatment can be reduced or even omitted during the first year (Andrade et al., 2014; Hölzel and Otte, 2003).

We obtained a significantly lower total target species number and total number of established individuals on the intensely fertilized plots (120 kg N ha^{-1} yr^{-1}) compared to unfertilized plots, findings which support the first part of hypothesis 2. This negative effect of fertilization on restoration success is in accordance with other studies (for example Foster et al., 2009; Jones and Hayes, 1999; Smith et al., 2000). Since most of the introduced species are adapted to at least moderately nutrient-rich site conditions the reasons might be the same as shown for frequent cutting. Nitrogen application increases aboveground biomass resulting in increased light limitation for understory species, which are then outcompeted (Borer et al., 2014). A moderate fertilization with 60 kg N ha^{-1} yr^{-1} did not significantly reduce the number of established target species and individuals in the present study, thus supporting the second part of hypothesis 2. This finding suggests that moderate fertilization did not lead to a significant lowering of the competitive ability of the sown species, which is important for restoration practice, because it allows for a moderate fertilization if an adequate biomass removal by cutting will be applied. Therefore, the respective meadows can provide hay with good fodder quality already during the restoration phase, which can increase farmers' acceptance of restoration actions.

Table 3
The effects of the fixed factors cutting, fertilization, rolling, cutting*fertilization, cutting*rolling and fertilization*rolling as well as soil pH on the numbers of established sown target species and individuals. Statistics were calculated using generalized linear mixed models (GLMM). Significant differences ($p < 0.05$) are indicated with bold face. Groups for cutting and fertilization are shown in Fig. 1.

	Number of target species			Number of target species individuals		
	df	*F*	*p*	df	*F*	*p*
cutting	**2**	**3.748**	**0.030**	**2**	**7.056**	**0.002**
fertilization	**2**	**3.706**	**0.031**	**2**	**11.033**	**0.000**
rolling	1	0.089	0.767	1	0.023	0.879
cutting*fertilization	4	0.177	0.950	**4**	**2.691**	**0.040**
cutting*rolling	2	0.734	0.484	2	2.398	0.100
fertilization*rolling	**2**	**5.300**	**0.008**	**2**	**8.861**	**0.000**
pH 2012	1	3.200	0.079	1	3.078	0.085

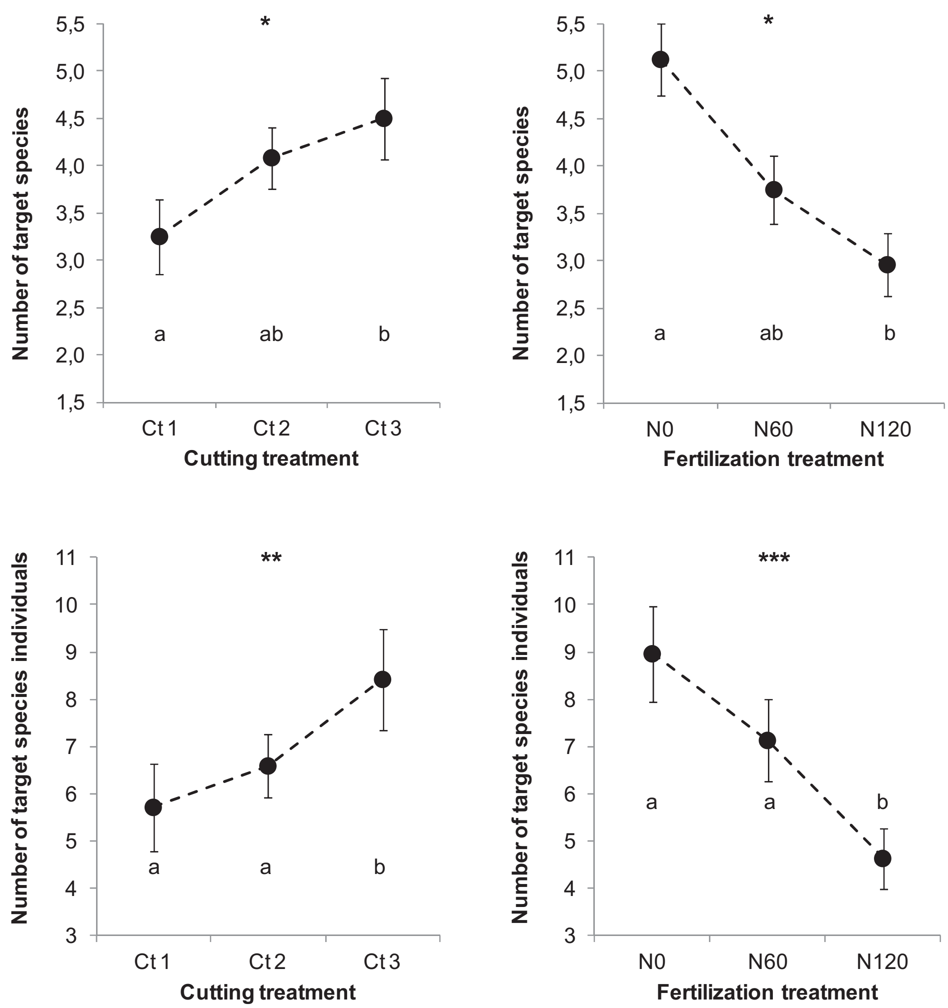

Fig. 1. The effects of the cutting and fertilization treatments on the numbers of established sown target species and individuals per microplot (0.25 m^2) in autumn 2012. Statistics were calculated using generalized linear mixed models (GLMM). Significant differences ($p < 0.05$) are indicated by different letters. Shown are means ($n = 24$) with standard error. n.s. not significant, $^*p \leq 0.05$, $^{**}p \leq 0.01$, $^{***}p \leq 0.001$.

Rolling had no effect on the number of established target species and individuals in the present study, thus hypothesis 3 cannot be supported. This may be due to the prismatic surface of the roll resulting in a patchy distribution of pressure. Closing frost cracks and structuring the soil surface may have even improved seedling conditions and thereby compensated for potential losses of seedlings by mechanical damage.

The significant interaction of fertilization and rolling is hardly interpretable in ecological terms, whereas the significant effect of the interaction between cutting and fertilization on the establishment of target species individuals supports the aforementioned main effects of cutting and fertilization. The conditions for the establishment of individuals diminish with higher biomass accumulation and nutrient supply, thus an adequate biomass removal by cutting is indispensable especially on fertilized sites.

In order to establish a large number of target species and individuals in the first year, we recommend a management treatment of cutting three times and to use no or only moderate amounts of nitrogen fertilizer.

At the species level, we found differences in the establishment success, which can be related to specific species traits thus supporting hypothesis 4. As already shown above, the mowing treatments affected seedling establishment in general, but the species responded differently to the mowing treatments, which is

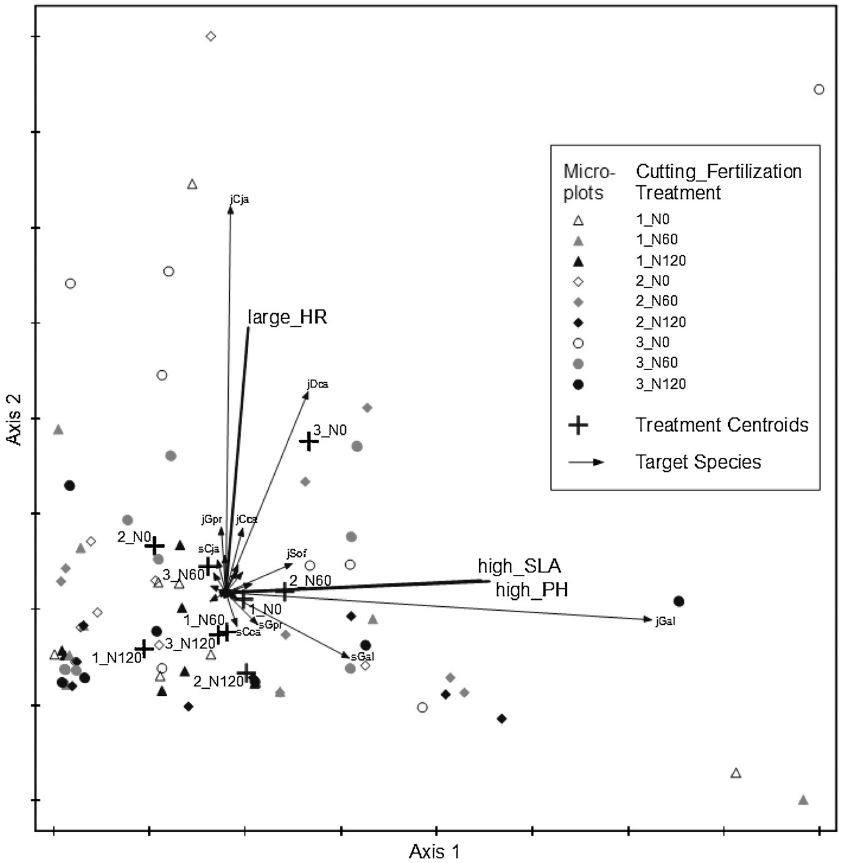

Fig. 2. PCA ordination diagram showing the distribution of all microplots based on the established individuals of every sown target species (j = juveniles, s = seedlings, for species abbreviations see Table 2) and post hoc correlations of each axis with species traits ($r > 0.8$ large_HR = large hemirosettes close to the ground, high_SLA = specific leaf area >2 mm^2 mg^{-1}, high_PH = potential height of at least 100 cm, compare Table 2). Microplots are labeled according to the cutting*fertilization treatment (compare Table 1) and centroids of all treatment groups are shown. Explained variance: axis 1: 27.4%, axis 2: 17.6%.

in line with Bissels et al. (2006). In the present study, species which are able to build large hemirosettes close to the ground could cope particularly well with frequent cutting as has been already assumed by Kahmen and Poschlod (2008). *Centaurea jacea*, *Daucus carota* and *Geranium pratense* are typical examples for this group of species. After cutting, they can quickly re-build dense hemirosettes and therefore permanently occupy the respective space. These species also profit from no or only moderate fertilization, which may be an effect of less dense stands and higher light availability near to the ground.

On the other hand, species having a high specific leaf area (SLA) and/or potentially reaching a height of at least 1 m were not restricted to specific cutting or fertilization treatments, which is also in line with Kahmen and Poschlod (2008). Having a large SLA and height enables these species to cope with different cutting and fertilization treatments. It can be assumed that species with such traits, for example *Galium album*, can on the one hand better compensate for reduced light-availability in dense stands caused, for example, by insufficient cutting, than species with a lower SLA and potential height. On the other hand, a high SLA, representing the relative growth rate of a species (Wilson et al., 1999), can also promote these species when a site is frequently cut. Therefore, a high SLA cannot be used as a predictor for species cutting response, as found by Díaz et al. (2001) for different intensities of biomass removal. Furthermore, a high SLA is said to be positively related to nutrient availability (Wilson et al., 1999). But, in accordance with Duru et al. (2014) and Andrade et al. (2014), who studied sites with different nutrient availability, we did not find any effects of different fertilization treatments on the establishment success of species with a high SLA, although our field observations indicated such a relation. We therefore suggest to use individual (site-depending) SLA instead of mean SLA from a database in future studies.

Altogether, integrating a species-trait approach into the procedure of the seed mixture composition may enhance restoration success. On the one hand, the management after sowing can be adapted toward a more frequent cutting if species with specific traits (such as large hemirosettes close to the ground) do not show the expected establishment success. On the other hand, it seems sensible to enhance the share of species robust to different management regimes if a frequent cutting during the first establishment year is not feasible.

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