SUCCESSFUL ESTABLISHMENT OF THE NATURA 2000 SPECIES *PULSATILLA PATENS* (L.) MILL. IN NEWLY RESTORED CALCAREOUS GRASSLANDS

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Abstract: In Europe, *Pulsatilla patens*, a species listed in Annex II of the habitats directive, is strongly endangered due to land use change. In Germany, only one large population has been preserved in a nature reserve north of Munich, but this population also declined from 27,000 individuals in 1991 to 9,500 individuals in 2003. Therefore, *Pulsatilla* seeds were propagated and sown on large-scale restoration fields, on which calcareous grasslands had been established after topsoil removal and transfer of seed-containing hay between 1993 and 2003.

The aim of our study was to study the performance of the newly established populations of *Pulsatilla patens* in comparison to the ancient population in the nature reserve. Population size was determined by a GPS-supported mapping and population structure was studied in relation to vegetation characteristics.

On three restoration sites of 0.42 to 1.4 ha area, new populations of 6,075, 16,145 and 13,511 *Pulsatilla patens* individuals respectively could be established. Population density varied between 0.96 and 3.84 plants per 1 m². Four years after sowing, many of the newly established plants were flowering and developed even more flowers than the plants in the nature reserve. The number of viable seeds per inflorescence was also higher on restoration fields than in the nature reserve. Our results indicate that re-introduction of *Pulsatilla patens* is most successful on topsoil-removal sites in combination with hay transfer.

Keywords: 6210 Semi-natural dry grasslands, calcareous grasslands, reintroduction, Natura 2000 species

Introduction

Pulsatilla patens, a vascular plant species listed in Annex II of the habitats directive, is strongly endangered in Europe. The last existing population of the species in Germany occurs in the nature reserve “Garchinger Heide” north of Munich. In this area, the population size decreased from 27,000 individuals in 1991 to 9,500 individuals in 2003, probably because vegetation management by mowing of alternating stripes did not provide enough gaps for the recruitment of seedlings and young plants (Röder & Kiehl 2006).

Within the nature reserve, the mowing regime was optimized to enhance the conditions for population persistence (Röder & Kiehl 2007a). Furthermore, the species was introduced in young calcareous grasslands, which had been restored by transfer of fresh seed-containing hay on ex-arable fields adjacent to the nature reserve (Kiehl & Pfadenhauer 2007). On these ex-arable fields species-rich calcareous grasslands had been present until the beginning of the 20th century.

Local nature conservation agencies and practitioners started to propagate seeds of *Pulsatilla patens* in order to establish new populations because it was not possible to introduce this early flowering species by hay transfer. A pilot study had shown, that introduction of *Pulsatilla patens* by sowing was more suitable than planting of juvenile plants, mainly because of lower costs (Röder & Kiehl 2007b). The same study also indicated that competition by tall vascular plants had a negative effect on seedling

recruitment and survival on nutrient rich ex-arable fields without topsoil removal, whereas seedlings established well in calcareous grasslands established by hay transfer on topsoil-removal sites. Therefore, large scale-experiments on the introduction of *Pulsatilla patens* seeds in calcareous grasslands restored by topsoil removal in combination with hay transfer were started in 2002/2003.

The aim of our study was to analyse the performance of the newly established populations of *Pulsatilla patens* in comparison to the ancient population in the nature reserve and hence to evaluate the success of species introduction. More detailed results of this study are presented by Röder & Kiehl (2008).

Figure 1. *Pulsatilla patens* plant introduced by sowing in calcareous grasslands restored by topsoil removal and hay transfer (photo: Daniela Röder, 2007)

Materials and methods

Seeds of *Pulsatilla patens* were propagated in close vicinity of the nature reserve "Garchinger Heide" (Munich gravel plain) in cooperation with a local enterprise specialized on propagation of wild plants. Seeds were sown with a sowing machine on three restoration fields on 25 August 2003 with a sowing density of 0.7 kg ha^{-1}. On one restoration field (RF 508A), topsoil had been removed down to the calcareous gravel and calcareous grassland species had been introduced by transfer of fresh seed-containing hay in 1993. Here, a species-rich vegetation with low-growing species typical for calcareous grasslands and with small vegetation gaps had established (Kiehl & Pfadenhauer 2007). On the other two restoration fields (RF 519A, RF 520A), topsoil removal was carried out in 2003 before sowing and hay transfer after sowing. In 2007,

both *Pulsatilla patens* plants and numerous calcareous grassland species introduced by hay transfer were present on this site.
On all three restoration fields, population size was determined by a GPS-supported mapping. Population structure was studied by counting individual plants of different age-state classes on 4 m² plots. These data were analysed in relation to vegetation characteristics (for details see Röder & Kiehl 2008).

Results and discussion

In 2007, new populations of 6,075, 16,145 and 13,511 *Pulsatilla patens* individuals respectively were mapped on the three restoration sites (Table 1). This means that in total more than 35,000 individuals were successfully introduced by sowing in comparison to less than 10,000 individuals present on reference sites in the nature reserve. Population density of *Pulsatilla patens* varied between 0.96 and 3.84 plants per 1 m² on restoration fields and was also much higher than on reference sites in the nature reserve. Population structure on RF 520 showed a high proportion of young plants but also many large plants flowering (Fig. 1). Four years after sowing, many of the newly established plants developed more flowers and significantly more viable seeds per inflorescence than the plants in the nature reserve (Röder & Kiehl 2008).

Obviously, the habitat conditions in young calcareous grasslands restored by topsoil removal and hay transfer were very suitable for the recruitment of *Pulsatilla patens* seedlings. Röder & Kiehl (2006) concluded that *Pulsatilla patens* needs both vegetation gaps for germination and some shelter to prevent desiccation of seedlings and young plants. In our sowing experiment, safe sites were provided by low-growing calcareous grassland plants on RF 508 (restored in 1993). On RF 519 and RF 520 (both restored in 2003), seedlings were probably protected from desiccation by the plant material from the hay transfer, which acted as a thin mulch layer (see also Röder & Kiehl 2008).

Table 1. Population size and population density of new populations of *Pulsatilla patens* established by sowing in 2003 on restoration fields in comparison to ancient populations on references sites in the nature reserve. Plant individuals were mapped in 2007 on restoration fields. Data from the nature reserve are from 2003.

Site	Area (ha)	seed weight (kg)	mean no. of plants m^{-2}	Total no. of plants	Establishment rate (%)
Restoration fields					
RF 508A	0.45	0.32	1.35	6,075	2.37
RF 519A	0.42	0.30	3.84	16,145	6.72
RF 520A	1.40	0.99	0.96	13,511	1.71
Reference sites					
Ancient grassland	20.98	-	0.46	9,577	-
Topsoil removal 1945	1.62	-	0.07	115	-

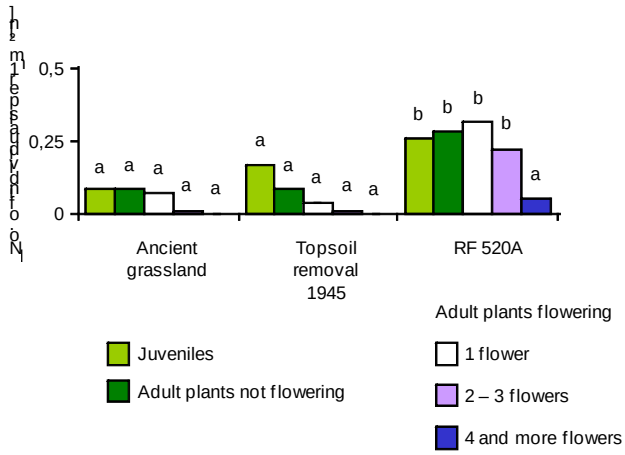

Figure 2. Population structure (age state classes) of *Pulsatilla patens* in a newly established population (RF 520A) in relation to population structure on reference sites in the nature reserve "Garchinger Heide" (ancient grasland and "Rollfeld" = topsoil removal 1945).

Conclusions

Our results show that the introduction of the Natura 2000 species *Pulsatilla patens* by sowing of seeds of local provenence was very successful in calcareous grasslands restored by topsoil removal and hay transfer. Both, vegetation gaps in low vegetation and protection of seedlings and young plants from desiccation are necessary for population establishment and persistence. Introduction of calcareous grassland species is only feasible when habitat conditions on restoration sites are suitable and long-term management of restoration fields by grazing or mowing can be ensured.

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