Agriculture, Ecosystems and Environment 130 (2009) 93–99

Contents lists available at ScienceDirect

Agriculture, Ecosystems and Environment

journal homepage: www.elsevier.com/locate/agee

Plant colonization of ex-arable fields from adjacent species-rich grasslands: The importance of dispersal vs. recruitment ability

Mathias Öster [a,*], Kristina Ask [a], Christine Römermann [b], Oliver Tackenberg [c], Ove Eriksson [a]

[a] Department of Botany, Stockholm University, SE-106 91 Stockholm, Sweden
[b] Institute of Physical Geography, University of Frankfurt, D-60438 Frankfurt, Germany
[c] Institute of Ecology, Evolution & Diversity, University of Frankfurt, D-60323 Frankfurt, Germany

ARTICLE INFO

Article history:
Received 30 November 2007
Received in revised form 1 December 2008
Accepted 6 December 2008
Available online 20 January 2009

Keywords:
Colonization
Dispersal
Grassland conservation
Grassland restoration
Recruitment limitation
Seed sowing

ABSTRACT

Species-rich semi-natural grasslands have declined drastically in Europe over the last century and occur in modern landscapes as small and isolated fragments. Recreation of these species-rich plant communities and increasing connectivity of remaining grasslands are important goals for nature conservation. Ex-arable fields located adjacent to species-rich grasslands have been suggested as targets for such recreation, but we still lack knowledge about the processes determining colonization from grasslands to ex-arable fields. We examined transects from species-rich semi-natural grasslands to ex-arable fields in a nature reserve located in southeast Sweden, and analysed relationships between observed colonization of ex-arable fields and two characteristics of species: dispersal ability and recruitment ability. Colonization of ex-arable fields was not related to dispersal ability, assessed as adhesive potential to animal coat, wind dispersal potential and seed mass (related to seed production), but was positively related to recruitment ability, assessed by sowing experiment. The same relationships appeared when using a performance index from sowing experiments conducted in the UK. We conclude that recruitment ability is a key factor for colonization of ex-arable fields. In our study, around 50% of semi-natural grassland species were able to colonize adjacent ex-arable field margins spontaneously within a time window of less than 50 years. Seed sowing is however needed to increase the speed of the colonization process, because increasing seed density promotes colonization of species with poor recruitment in ex-arable fields. Actions to increase area and connectivity of species-rich grasslands should consider incorporating ex-arable fields.

1. Introduction

In most parts of northern and western Europe, there has been a drastic decline in the extent of unimproved species-rich grasslands during the last 100 years (Poschlod and Bonn, 1998; Eriksson et al., 2002). In many countries, including Sweden, Finland and the UK, less than 10% of the original extent of these grasslands remains (Fuller, 1987; Bernes, 1994; Vainio et al., 2001). Lost grasslands have mainly been transformed to arable fields or forests, on various time scales (Dahlström et al., 2006). Those semi-natural grasslands that remain often contain a very high species richness of plants (e.g. Eriksson and Eriksson, 1997; Öster et al., 2007), as well as many other groups of organisms, such as fungi (Öster, 2008), and insects and birds (Söderström et al., 2001). Considerable resources are allocated to maintain the still existing semi-natural grasslands, and to restore or recreate such grasslands.

One method to increase the area and connectivity of species-rich grasslands is to recreate such plant communities on former arable fields (henceforth ex-arable fields) that are presently used as pastures. Along with other methods to achieve this goal, e.g. sod cutting (Bakker and Berendse, 1999), sowing of seed mixtures of grassland species into ex-arable fields has received a lot of attention (e.g. Pywell et al., 2002, 2003, 2007; Walker et al., 2004; Lindborg, 2006). A general conclusion from these studies is that seed availability seems to be a key factor limiting re-assembly of species-rich grassland communities, at least in fields that are not too nutrient rich. A high phosphorous content in the soil may however constrain establishment of grassland communities (Janssens et al., 1998). The long history of management, and thus the long time available for colonization, may thus be one of the mechanisms that have contributed to build up the high species

* Corresponding author. Tel.: +46 8 16 38 29; fax: +46 8 16 22 62.
E-mail addresses: mathias.oster@botan.su.se (M. Öster), kristina.ask@botan.su.se (K. Ask), roemermann@em.uni-frankfurt.de (C. Römermann), Tackenberg@bio.uni-frankfurt.de (O. Tackenberg), ove.eriksson@botan.su.se (O. Eriksson).

0167-8809/$ – see front matter © 2008 Elsevier B.V. All rights reserved.
doi:10.1016/j.agee.2008.12.005

richness in species-rich grasslands (Eriksson and Ehrlén, 2001; Eriksson et al., 2002, 2006). A likely limiting factor for colonization of new grasslands, on ex-arable fields, is therefore lack of time.

Many studies on recreating species-rich grassland communities on ex-arable fields have focused on site specific factors, such as management (disturbance) and soil conditions (e.g. Bakker and Berendse, 1999; Römermann et al., 2005a; Pywell et al., 2007). However, as seed sowing experiments show that seed availability is limiting establishment on ex-arable fields, it is likely that the surrounding landscape will also affect colonization. If few source populations are available in the vicinity of the target area for recreation of species-rich grassland, the degree of seed limitation will be particularly strong. Even if source populations exist, some species with good establishment ability may nevertheless be strongly limited by dispersal, even on a small scale (Coulson et al., 2001). If seed sowing is not carried out, it has been suggested that management alone (e.g. grazing) is unlikely to result in recovery of high species richness on ex-arable fields (Critchley et al., 2003), although natural colonization slowly increases the similarity between ex-arable fields and grasslands (Hansson and Fogelfors, 1998). In Sweden, where species-rich grasslands are still relatively abundant, ex-arable fields located adjacent to species-rich grasslands, are particularly interesting for recreation of such grassland communities. If successful, such recreation would increase the total area of species-rich grassland, and increase connectivity of remaining grasslands. It is however poorly known to what extent adjacent species-rich grasslands contribute to enhance species richness on ex-arable fields, and which factors are most important in determining spread of species to ex-arable fields. Three major processes can be postulated: (i) species seed production on the species-rich grasslands, (ii) the ability to disperse from the adjacent species-rich grasslands to the ex-arable field, or (iii) the ability to establish on the ex-arable field provided that dispersal has occurred.

In line with an increasing recognition of a landscape level perspective on conservation of semi-natural grasslands (e.g. Lindborg and Eriksson, 2004; Cousins, 2006), studies have addressed the question how to construct economically sustainable grazing regimes, that may be profitable for farmers, perhaps even without dependence on subsidies. Kumm (2003, 2004) suggested that a solution may be to create large areas incorporating both the remaining grasslands (which presently are often kept isolated by fencing) and ex-arable fields. In such a management system it would be commonplace that a species-rich grassland is located adjacent to grassland with, at least initially, low species richness. Still, both types of vegetation would be grazed by the same animals, which would freely move across the borders between the grasslands.

With these considerations as a background, we examined three questions relevant for evaluating the potential conservation benefits of "large grazing areas" (*sensu* Kumm, 2003, 2004). (1) Given a time window of less than 50 years, how large fraction of semi-natural grassland species is able to spontaneously colonize adjacent ex-arable fields? (2) Is there a positive relationship between actual colonization of ex-arable fields and aspects of the dispersal ability of the species? (3) Is there a positive relationship between actual colonization of ex-arable fields and the recruitment ability of the species? Dispersal here means the ability of seeds to become transported in space, and recruitment means the ability to germinate and survive the early life stages, given that seeds have been dispersed to the site. This study was done within a relatively limited area in southeast Sweden, within which both the age of the ex-arable fields and the soil conditions were fairly homogeneous. Effects of variation in the available time for colonization, and soil conditions, were therefore outside the scope of this study.

2. Materials and methods

2.1. Field sites and species survey

The field study was carried out in or in the close vicinity of Nynäs nature reserve, c. 100 km south of Stockholm, Sweden (50°50′N, 17°24′E). Nynäs nature reserve contains a mosaic of species-rich semi-natural grasslands, arable fields, ex-arable fields and various types of forests, mainly coniferous or mixed deciduous-coniferous forests. The areas with the highest nature conservation interest are the species-rich grasslands (Eriksson and Eriksson, 1997; Cousins and Eriksson, 2001, 2002). The study region is situated in the boreonemoral zone, a transition zone between the nemoral deciduous forest zone and the boreal zone (Walter, 1979). In this vegetation zone, open grasslands can only be maintained as result of management which historically has been grazing or mowing. From a conservation perspective, the most urgent problem is that semi-natural grasslands are abandoned, or that the intensity of grazing (which the most common management today) is too low, resulting in a succession to forest. Until the late 19th century, the area covered by the present-day nature reserve in Nynäs contained extensive semi-natural grasslands (c. 44% of the area), but land use change during the 20th century resulted in the transformation of most semi-natural grasslands into either arable fields or forests (Cousins, 2001; Cousins et al., 2002). The soil conditions in the grasslands and fields are fairly homogeneous. pH is in the range 5.2–5.8, and the phosphorous content is in the range 1.5–2.4 mg/100 g dry soil (Eriksson, unpublished), which is below the level (5 mg/100 g dry soil) suggested by Janssens et al. (1998) as a threshold value for successful colonization of ex-arable fields.

Seven field sites were used. Five of these were located within the Nynäs nature reserve, one site was located near a farm 1 km north of the reserve, and one site was located in Horsvik (4 km south of the reserve). All sites included a border between a species-rich grassland and a grazed pasture on an ex-arable field. All sites were grazed by cattle allowed to freely move across the border between the grasslands and the ex-arable field. The change in land use on the fields, from crop production to grazing, took place 30–50 years ago (Cousins, unpublished). Since then, all sites have been grazed yearly, thus preventing litter build-up and tall vegetation. At each of the seven sites, two transects were placed perpendicular to the border between the semi-natural grassland and the ex-arable field. Each transect was 13 m, with the border (which is fairly sharp and recognizable by a remnant of a shallow ditch) placed at the third meter. Thus, the transects reached 3 m into the grassland and 10 m into the ex-arable field. At each meter interval, all species within a square (0.5 m × 0.5 m, 3 in the grassland, 10 in the ex-arable field) were recorded. The two transects at each site were placed in parallel, c. 5 m apart. The field inventory was carried out in 2004. The nomenclature follows Stace (1997).

2.2. Sowing experiment

A sowing experiment was carried out on each of the seven sites, using 19 species (Table 1). The species were chosen based on two criteria. Firstly, they are considered as "typical" for semi-natural grasslands in Sweden (Ekstam and Forshed, 1992), and occur in species-rich semi-natural grasslands in the Nynäs nature reserve. Secondly, as far as possible the species list was adjusted to conform to Pywell et al. (2003), who reviewed and summarized results of similar experiment in the UK, thus enabling comparisons of the results on recruitment on ex-arable fields in two different regions of northern Europe. Of the 19 species used in our experiment, 17 were included in Pywell et al. (2003) (Table 1).