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To seed or not to seed in alpine restoration: introduced grass species outcompete rather than facilitate native species

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ABSTRACT

Anthropogenic disturbance in alpine ecosystems is on the increase, and knowledge is needed about restoration methods and their long-term effects in these environments. Sowing seeds from introduced grass species has been a common approach to encourage the growth of new vegetation, but there is disagreement over the long-term effects. Little is known about native alternatives and their ability to promote establishment of native vegetation. We compared vegetation cover, species richness and soil conditions in a long-term field experiment in seeded sites and unseeded reference sites 21 years after seeding with a commercial seed mixture. We also tested germination and establishment of an introduced grass *Festuca rubra* and its native congener *Festuca ovina* and their effect on the establishment of the native shrub *Betula nana* in a greenhouse experiment in different soil types. In the long-term field experiment, the introduced *Festuca* species outcompeted rather than facilitated natural vegetation recovery in the seeded sites. Total vegetation cover was significantly higher in the seeded sites, but native vegetation cover and species richness were significantly higher in the unseeded sites. In the greenhouse experiment, the native *F. ovina* showed a tendency to facilitate the seedlings of *B. nana* in contrast to the introduced *F. rubra*, which clearly suppressed *B. nana* seedlings. However, seedlings of the native shrub *B. nana* performed best when seeded without any of the species that are presumed to be facilitators or nurse species. Suppression by seeded grass was stronger on commercial peat soil compared to fine mineral soil and coarse soil. When seeding is used in restoration efforts, it is important to choose species that do not compete strongly with the natural vegetation. Fertilization and other soil improvements may even favor strong seeded competitors at the expense of native species. Hence the combination of seeding introduced species and improving the soil may delay successful alpine natural vegetation recovery.

1. Introduction

Human-caused disturbances from the exploitation of natural resources, infrastructure development, and tourism are increasing in alpine areas, putting ecosystems, species under pressure. The accompanying loss of biodiversity, and habitat fragmentation suggest a need for ecological restoration to improve alpine ecosystem recovery (Aradottir and Hagen, 2013; Bullock et al., 2011). Natural recovery after disturbances in alpine, arctic environments is usually a slow process (Harper and Kershaw, 1996; Jorgenson et al., 2010; Rydgren et al., 2013). In these areas, the establishment, growth of plants, soil development all occur under conditions with short growing seasons, low summer and winter temperatures, and strong winds. If the disturbances are severe the mineral soil is exposed resulting in the loss of soil nutrient, and soil seed bank, which in turn creates increasingly deteriorating conditions for vegetation recovery.

Assisted revegetation may speed up the restoration process in severely disturbed sites where succession proceeds slowly (Forbes and Jefferies, 1999; Jorgenson et al., 2010). A number of techniques are used for this purpose, based on ecological, monetary, aesthetical, logistic, and speed considerations (Aradottir and Hagen, 2013; Comín, 2010; Perrow and Davy, 2002). The main ecological purpose of these techniques is to provide the site with conditions that will facilitate further recovery, such as the accumulation of nutrients, provision of shade and lee, and protection from herbivores (Callaway et al., 2002). Positive results are particularly likely in alpine habitats, since they are subject to a variety of stresses and disturbances, and the abiotic environment is the primary limitation for plant growth (Brooker and Callaghan, 1998).

The use of seeds from introduced grass species, often in combination with fertilizer application, has been commonly used over

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the decades to establish new vegetation cover in alpine areas (Forbes and Jefferies, 1999; Jorgenson and Joyce, 1994; Krautzer and Wittmann, 2006; Urbanska and Chambers, 2002; Younkin and Martens, 1987). Revegetation with commercially available seed mixtures has stimulated the development of native plant communities over the short term (Chapin and Chapin, 1980; Gretarsdottir et al., 2004; Holl, 2002). Nevertheless there is limited documentation of the long-term effects of revegetation efforts, especially in alpine environments. The long-term ecological effects of seeding are disputed (Densmore, 1992; Forbes and Jefferies, 1999; Helm, 1995) and so is the effect of fertilization. Nutrient application has been demonstrated to favor competitive introduced species and inhibit the establishment of native, desirable species (Inouye et al., 1987), and decrease species diversity (Carpenter et al., 1990; Redente et al., 1984). Other studies have shown that seeding has an insignificant effect on the long-term vegetation recovery but that other factors, such as the grain size of the substrate are far more important (Rydgren et al., 2013). This suggests that the significance of seeding is dependent on context. Introduced seeded grass species may even inhibit or delay the establishment and growth of native tundra plants which is tangible as lower native species diversity and a long-lasting dense cover of seeded species in alpine seeded sites (Densmore, 1992; Hagen and Evju, 2013).

There are other pros and cons of seeding introduced and native species when attempting to facilitating revegetation following severe disturbance. Native plant material is better adapted to local ecological conditions (Grant et al., 2011; Krautzer et al., 2011) and does not contribute new genotypes that may not be adapted to the local conditions or may outcompete (or replace or cross-breed with) the native genotypes (Parker and Reichard, 1998). Native species also improve visual continuity with the surrounding local vegetation and interact better with natural communities (Urbanska and Chambers, 2002). However, knowledge is sparse about the use of native species and their performance over time in revegetation efforts. Seeding of native species may result in more seedling establishment compared to seeding of introduced species during restoration (Tinsley et al., 2006, Petersen et al., 2004, Olivieira et al., 2013). Thus it is highly relevant to see if the use of native seeds can be a suitable solution as their use offers the advantages of seeding without the negative effects from introduced species. A native alternative may perform on pair with introduced species, and may also coexist better with other native species, making the native more suitable for natural restoration efforts. Commonly used introduced species may have different traits and moisture and nutrient needs compared to a native congener, which can be tested under controlled experiments. Laboratory experiments that compare germination of seeds from native populations and traditional commercial seeds can reveal these traits. Field studies and laboratory experiments can complement to one another in exploring if and how seeding facilitates the long-term development of a vegetation cover.

The Hjerkinn military firing range in the Dovre Mountains of central Norway was used for military purposes from 1923 until 2006 (Norwegian Defence Estate Agency, 2010). During the last twenty years different revegetation interventions have been attempted in the firing range to reduce the negative impact from military activity on the vegetation and landscape. In 1999 the Norwegian Parliament decided to terminate all military activity, remove all military installations, and *"restore the ecosystem to its original state and for future nature protection (National Park) . . ."* (Anon., 1998). Due to this ambitious decision introduced plant material is now undesirable for restoration efforts (Martinsen and Hagen, 2010). Seeds collected from local plants of native *Festuca ovina* have been cultivated for upcoming restoration efforts (Martinsen and Oskarsen, 2010). Our study explores whether the use of native species in the future is likely to favor restoration more than the traditional procedure of using introduced species.

The objective of this study is to evaluate the effects of seeding with a commercial seed mixture on the establishment of the natural vegetation in Hjerkinn military firing range after 21 years. We also experimentally explored the conditions under which a native species alternative can improve the restoration of disturbed alpine sites. We tested: (1) whether seeding facilitated the cover of the natural vegetation over the long term (2) whether the long-term facilitation effect of seeding an introduced grass depends on soil conditions (3) whether the introduced grass species performs better than its native congener in a greenhouse experiment, and finally, (4) how soil conditions affected recruitment of a native shrub when grown together with the introduced and native congeners.

2. Methods

2.1. Study sites

The study site is situated between 1060 and 1240 m a.s.l. inside the borders of the former Hjerkinn military firing range (63 °N, 10 °E) at Dovre Mountain, Norway, in the low alpine vegetation zone, with a growing season of about 115 days (Moen et al., 1999). The mean annual July temperature (1997–2006) at the closest weather station (Fokstugu, 17 km SW of the site, 972 m a.s.l.) is 11.2 °C and the mean temperature in January is −6.4 °C. Mean annual precipitation (1997–2006) was 444 mm (Norwegian Meteorological Institute, 2010). The site is on Precambrian bedrock, consisting mainly of metamorphosed rock covered by calcium-poor glacial sediments (Norwegian Geological Survey, 2011). The vegetation is dominated by lichen and dwarf shrub heaths, shrubs with *Salix* spp., meadows, and scattered bogs and fens (Norwegian Institute for Soil and Forest Mapping, 1999).

2.2. Field study

We studied vegetation 21 years after seeding in disturbed road verges. The design was set up in ten disturbed sites, and in each site one part was seeded and the other was unseeded (called the reference). In 1989, the 10 verges were seeded with a commercial seed mixture (7 kg/1000 m^2) consisting of *Agrostis capillaris* "Leikvin", *Festuca rubra* "Leik", *F. rubra* "Encylva" and *F. rubra* "Koket" and fertilized with a commercial granulate fertilizer (50 kg/1000 m^2). Sheep, musk oxen and wild reindeer are found in the area and may have grazed the sites occasionally.

In July and August 2010 we placed an open transect with five 0.5 × 0.5 m plots, separated by a distance of 1 m, at each of the ten seeded and their corresponding reference sites (in total 100 plots). We recorded species abundance as subplot frequency out of 16 subplots (12.5 × 12.5 cm), and visually estimated the total cover (%) of graminoids, herbs, evergreen and deciduous dwarf-shrubs, lichens, bryophytes, biological soil crust, overall cover and species richness in the 100 plots.

The soil was visually classified by its dominant particle size according to Halvorsen et al. (2008), using classes 3–6 (3:dominated by fine sand; 6:dominated by coarse gravel). Five soil samples were taken from the upper 5 cm of the soil at each site in a dry period on 8 August 2010, and kept in a freezer at −20° C until analysis. Soil moisture was determined by drying (115 °C for 24 h) and reweighing. The dry soil samples were then sifted (2 mm mesh width) for analyses of organic content (loss on ignition; ignited at 550 °C for 8 h) and pH [in distilled water with a PHM82 Standard pH meter (Radiometer Copenhagen)].