Revegetation of roadsides in Central Spain: factors controlling plant colonization and establishment

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Abstract
We investigated the importance of neighboring vegetation for the colonization of new road slopes and the success of hydroseeding. To this end we conducted a field study on road slopes of two highways. We found that surrounding vegetation was the most important factor determining the species richness of the road slope vegetation, as a high proportion of the species on the road slopes was in common with the species of the local vegetation (85 - 90%), while the contribution of species from hydroseeding (6-8%) and the seed bank (1-2%) was much lower. No effect was found of the hydroseeding treatment on species richness or vegetation cover. Between the two road slope types a difference in vegetation cover was shown, which can be explained by a difference in nitrogen content of the soil. Our results lead to the conclusion that the development of plant cover was mainly limited by the soil fertility of the sites.

Keywords Hydroseeding, Revegetation, Road slopes, Seed germination, Site quality

Introduction

With the construction of roads and railways original ecosystems are changed and fragmented, while the effects on plants and animals are severe (Forman *et al.* 2002). At the same time, the accompanying movements of soil create new verges. The RECOTAL project (Restauracion Ecologica de Espacios Afectados por la Construccion de Infrastructuras) is aimed at the mitigation of the negative impact of construction on the plant communities and investigates new techniques of revegetation. Our study takes part in the RECOTAL project and explores the revegetation success of new roadsides.
After construction activities, road slopes initially lack vegetation which makes them vulnerable to water erosion and increase their instability. To protect the soil from erosion the current strategy of reclamation is to provide a quick plant cover. Seeds of fast growing commercial species are sown. However, recent studies in Mediterranean environments have questioned if vegetation establishment on road slopes is limited by seed input (Bochet *et al.* 2007). Standard revegetation techniques, like hydroseeding, often fail to reach a plant cover higher than 10%, due to low fertility and water shortage (Bochet and García-Fayos 2004). By hydroseeding a mixture of water, seeds, fertilizers, fixing substances and mulches is sprayed over the new road slopes. In order to be able to develop a successful revegetation method, a better understanding is needed of processes that determine seed germination and plant establishment. To this end we conducted a field study on road slopes of two highways.
We investigated the importance of neighboring vegetation for spontaneous colonization and the applicability of hydroseeding for the revegetation of road slopes.
An experiment was set up on two types of road slopes: roadcuts and embankments. In this study we examined 1) the relative contribution of seeds from neighboring

vegetation in plant colonization by comparing the floristic similarity between road slopes, neighboring vegetation and local vegetation, 2) effects of hydroseeding and slope type on vegetation cover, species composition and species richness.

Materials and methods

The study area was located in Central Spain, near Barajas International Airport (40º 29'N, 03º34'W) 12 km to downtown of Madrid, on the sides of two access roads to the airport: M-12 and M-13. Two types of road slopes were selected: roadcuts (by excavation) and embankments (by compacting and covering with topsoil). In each road slope four treatments were applied: hydroseeding with a standard seed mixture, hydroseeding with an alternative seed mixture (mainly native species), hydroseeding with the standard mixture and plastic sheets, and no hydroseeding (control). For each treatment there were nine replicates on the roadcuts and 6 replicates on the embankments. Plot size was 6 x 10-25 m^2. In the surrounding area plots were established on existing vegetation at a distance of 0-30 m to the experimental plots. In 2004 hydroseeding was carried out. Records of species number were made in May 2005, 2006 and 2007 in each plot. In 2005 species number was also recorded in the surrounding plots. An assessment was made of the success of species establishment according to species frequency and relative abundance on the road slopes. Frequency was obtained from the number of road slopes in which a species was present. Relative species abundance was estimated as their frequency in the four treatments of each road slope. A species was considered successful when it had a frequency > 50% and an abundance > 2 in the road slopes where the species was present.

Data were analyzed with the statistical package SPSS. We performed analysis of variance (ANOVA) with year and slope type as factors, and with slope type and origin as factors.

Results and discussion

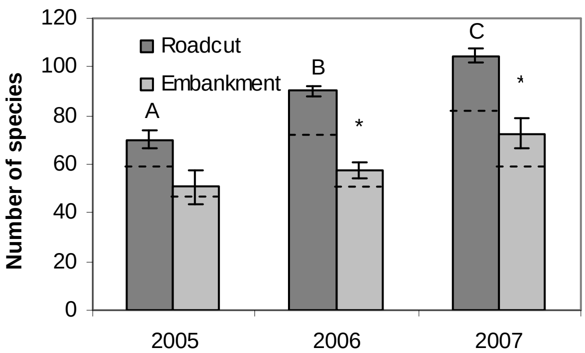

Fig. 1 Mean total number of species, and number of species in common with the local vegetation (-----), of the vegetation on the roadcuts and embankments in 2005, 2006 and 2007. Bars indicate ± SE (roadcuts n = 9, embankments n = 6). Different capital letters indicate significant different means between years within roadcuts. * indicate significant slope type effects p<0.05.

Over the years there was an increase in species richness on the road cuts (Fig. 1). The effect of year was significant for the total number of species and the number of species in common with the local vegetation (the local vegetation consists of the total of neighboring vegetation). Contrary to the roadcuts, no significant effect of year was found on the embankments, which was further indicated by a significant year * slope type interaction. Slope type clearly had a significant effect on the species richness, and on the number of species in common with the local vegetation (Fig. 1). The vegetation on the roadcuts had a significant higher species richness and number of common species than the vegetation on the embankments. However, this pattern of species number was contrary to the results on vegetation cover of Mola et al. (submitted). They found that vegetation cover was higher on the embankments than on the roadcuts. The topsoil of the embankments had a higher nitrogen and organic matter content, while the soil fertility of the roadscuts was very low (Mola *et al*. submitted). Probably this difference in soil fertility had led to a higher plant productivity and therefore a higher vegetation cover on the embankments. It is often found that beyond a certain level of productivity a further increase in productivity and coverage results in a lower species richness (Casado *et al*. 2004) due to an increased interspecific competition for light, nutrients or water. This could be an explanation for the lower species richness we found on the embankments.

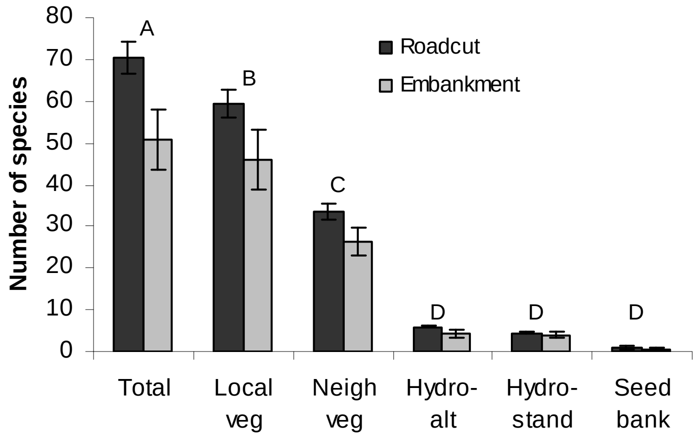

Fig. 2 Mean total number of species, and number of species in common with a) the local vegetation b) neighboring vegetation, c) alternative seed mixture, d) standard seed mixture, d) seed bank, in the vegetation on the roadcuts and embankments in 2005. Bars indicate ± SE (roadcuts n = 9, embankments n = 6). Similar capital letters indicate there are no significant different means between origins of seeds $p<0.05$.

The importance of the surrounding vegetation for the colonization of the road slopes is shown by the high proportion of species which were in common with the species of the local (85 - 90%) and neighboring (48 - 52%) vegetation (Fig. 2). The contribution of the species from the alternative hydroseeding mixture, the standard mixture and the seed bank was much lower, consisting of only 8%, 6 - 8%, and 1- 2 %, respectively. However, the number of species used in the seed mixtures was also low: 12 species in

the alternative and eight in the standard mixture. The seed bank was very poor and consisted of seven species.
The used hydroseeding practice seemed to have failed for the quick development of a vegetation cover, as no differences were found in vegetation cover between the different treatments (Mola *et al*. submitted).
In order to get an indication of the potential suitability of species for hydroseeding, an assessment was made of their establishment success. Of the 243 species found in the vegetation of the road slopes only a small proportion was established successfully: 42 species on the roadcuts (17%), and 30 species on the embankments (12%). Three species of the alternative seed mixture were successfully established on the roadcuts and embankments, and of the standard mixture three and four species respectively. Of the seed bank, two species were established successfully on both road slope types.

Conclusions

The existence of surrounding natural vegetation seems to be the most important factor determining species richness of the road slope vegetation. However, many species occurred at low frequency. To prevent erosion, a quick development of vegetation cover is needed.
Our results lead to the conclusion that the development of plant cover was limited by the soil fertility of the sites, as the difference in vegetation cover we found between the slope types was explained by a difference in initial soil fertility, while there was no difference in seed rain (Mola *et al*. submitted). This is also consistent with the results of Balaguer (2002) and Tormo et al. (2007) who found increased vegetation cover by top soiling.
Therefore, we suggest that efforts should be directed to improve the abiotic conditions of the site and select species which are most adapted to the harsh conditions of new road slopes. Further studies should be executed on the germination and seedling establishment of successful species to investigate their suitability for hydroseeding.

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