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# Which conditions determine the presence of rare weeds in arable fields?

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ABSTRACT

The intensification of agricultural management has caused some weed species to become rare in arable farming systems. It is difficult to disentangle which management practices are the least harmful for the conservation of rare arable weeds because of their sparse presence. In this research, we overcame the limitations of previous analyses of rare weeds by analyzing them in a large number of plots (1957) at the edges of multiple organic fields (304), which maximized the probability of detecting these species. We evaluated the relationships between farming practices and local site conditions and the presence of rare arable species that are characteristic of cereal fields.

We detected 46 of the 65 rare weeds that are known to inhabit the study area, but their frequency was very low. Cereal crops, either alone or in mixtures with legumes, enhanced the probability of finding rare weed species, while fertilization had a detrimental effect. Other management practices that were considered had no effect on the presence of rare arable weeds. However, selected rare species tended to fare better under particular local conditions and to be favored by specific management practices. In contrast, a significant amount of the variance of the rare weed presence was explained by farm-related and field-related random factors. Thus, the occurrence of rare arable species is apparently determined by stochastic factors that may be related to the local species pool that likely depends on the history of fields and farms. Therefore, conservation efforts should be focused on areas currently inhabited by rare arable species.



## 1. Introduction

Conserving arable weed species is somewhat problematic because their preferred habitat, arable fields, is primarily devoted to crop production (Fried et al., 2009). Increases in farming efficiency to enhance productivity have resulted in fields becoming less diverse, with few non-crop plants tolerated (Robinson and Sutherland, 2002). Agriculture has repeatedly been identified as one of the main causes of biodiversity loss worldwide (Elsen, 2000; Rich and Woodruff, 1996; Storkey et al., 2012). This is primarily due to the large cropland areas that are devoted to grow crops, which diminish non-crop habitats such as hedgerows and field margins, and the widespread use of pesticides and fertilizers (McLaughlin and Mineau, 1995). Therefore, conserving farmland biodiversity requires less intense farming practices (Tscharntke et al., 2005).

In recent decades, many arable weed species have suffered such a critical population decline that they have become rare or even locally extinct in many countries (Baessler and Klotz, 2006; Cirujeda et al., 2011; Fried et al., 2009; Storkey et al., 2012). Many of these species are found in the Red Data Lists of some European countries (Cheffings and Farrel, 2005; Kleijn and van der Voort, 1997 Türe and Böcuk, 2008), which constitutes the basis for most conservation strategies (Aboucaya et al., 2000; Kleijn et al., 2006). However, in Spain and other countries in the Mediterranean area, rare arable weed species are not included in the Red Data Lists or in conservation plans because these species are considered non-native and dependent on the maintenance of artificial habitats (Sáez et al., 2011). Conservation of rare arable species is crucial because of their intrinsic value as both components of biodiversity and key indicators of traditional and low-intensity agriculture. In addition, these rare species provide a greater variety of forms, compositions and functions than do the few crop species that dominate arable land and constitute a valuable resource for

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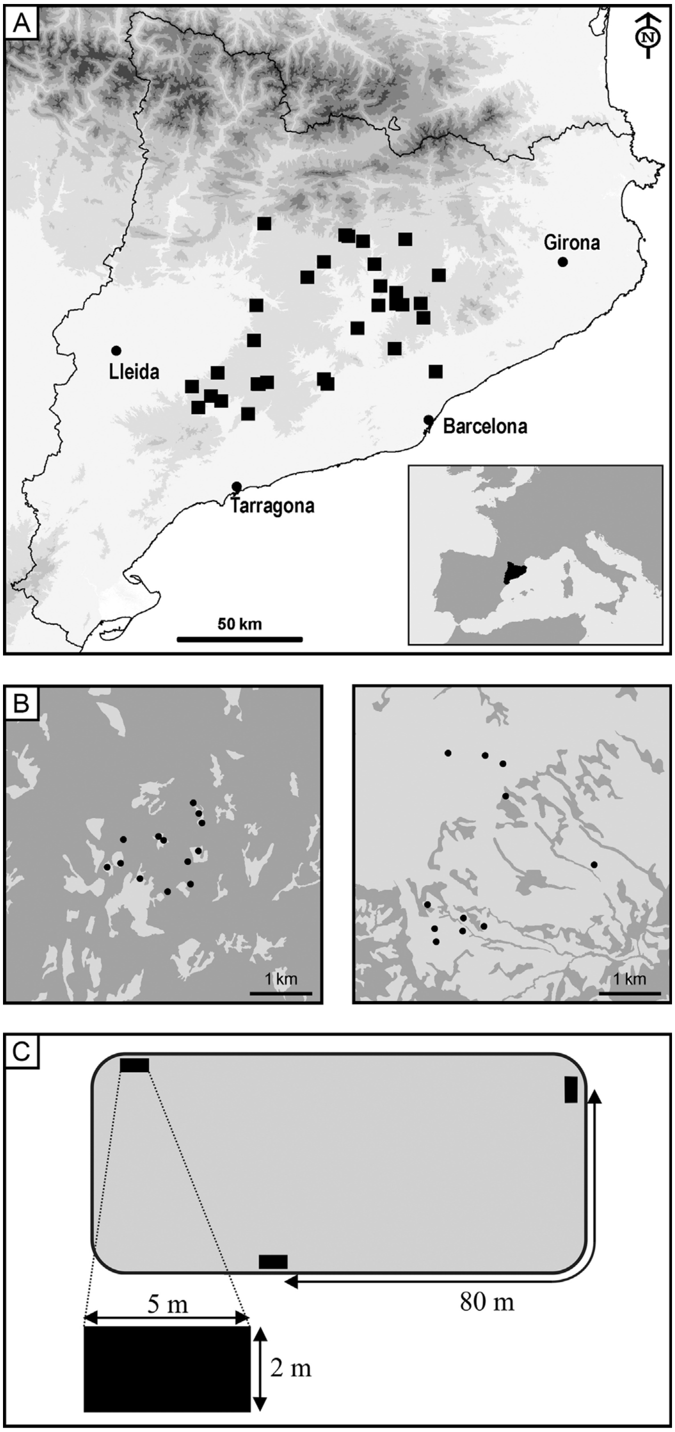


**Fig. 1.** (A) Locations of the 32 farms (squares) within Catalonia (NE Spain). Gray tones indicate elevation contours of 500 m. (B) Fields sampled (dots) at two farms taken as examples of complex (left) and simple (right) landscapes. Light gray represents arable habitats while dark gray includes other natural and semi-natural habitats. (C) Plots of 2 m × 5 m size spaced 80 m apart from each other were surveyed within each field.

pollinators, herbivores, predators and parasitoids (Caballero-López et al., 2010; Hawes et al., 2003; Tscharntke et al., 2005).

The distribution of arable weed species is determined by many parameters, among which history of land management and landscape composition, weather conditions, seed dispersal and other stochastic factors can play an important role (Ryan et al., 2010). Nevertheless, it is widely acknowledged that less intensive farming practices, such as those used in organic farming where herbicide and chemical fertilizer inputs are banned, tend to be beneficial for the richness and diversity of arable species (Cirujeda et al., 2011; Gibson et al., 2007; Kleijn et al., 2009), as well as the occurrence of rare arable weeds (Romero et al., 2008). However, there is considerable variation in management intensity among organic farms (Armengot et al., 2011a; Clough et al., 2007). This leads to highly versatile and seemingly contradictory effects of organic vs. conventional farming on diversity (Bengtsson et al., 2005). Thus, it may be appropriate to consider particular management practices to evaluate their impact on the presence of rare arable species.

Several studies have shown how weed species diversity is determined by the surrounding landscape, which acts as a refuge and source of propagules that can colonize crops (Gabriel et al., 2005; José-María et al., 2010; Poggio et al., 2010; Roschewitz et al., 2005; Solé-Senan et al., 2014). For this reason, it is important to consider the composition and amount of natural and semi-natural habitats that are adjacent to fields and landscape structure as factors that may contribute to variations in weed diversity.

The purpose of our research was to determine which field and local conditions are more suitable for the occurrence of rare arable species and to outline appropriate management practices that may promote their conservation. The specific objectives of this study were (1) to assess the effects of farming practices and local conditions on the occurrence of rare weed species within fields and (2) to investigate similarities between the responses of selected species to these variables. This study overcomes limitations of analysis that are related to low frequencies and usually affect studies of rare arable species, by surveying them in many plots at the edges of multiple organic fields where those species are most likely found (José-María et al., 2010; Kovács-Hostyánszki et al., 2011). Thus, this sampling method maximizes the probability of detection of each rare species (Thompson, 2004).

## 2. Material and methods

### *2.1. Study site*

The sampling was conducted in 2011 in Catalonia, northeastern Spain (41°22′–42°06′N; 0°59′–2°12′E). We selected organically managed fields from 32 farms within an area spanning 100 km × 80 km (Fig. 1). The average (±standard error) altitude of the surveyed sites is 558 m a.s.l. (±30 m and ranging from 95 to 871 m a.s.l.). The fields have basic soils with loamy and clayish textures. The climate is Mediterranean, with mean annual temperatures of 12.6 ± 0.2 °C and an average precipitation of 637 ± 21 mm (Ninyerola et al., 2005). Average monthly temperatures are always positive, but frost can occur from December to February, and is normally restricted to a few hours per day. Natural habitats in the study area include pine (*Pinus halepensis* Mill. and *P. nigra* Arnold) and oak (*Quercus ilex* L. and *Q. faginea* Lam.) woodlands, shrublands, small stands of perennial-dominated grasslands, and riverine vegetation.

### *2.2. Plant survey*

A total of 304 organically managed fields were surveyed during May and June 2011 (just before harvest). The selected fields had been sown in the previous growing season with the annual crops that are usually included in the winter cereal crop rotation (small grain cereals, legumes, ryegrass and crop mixtures containing cereals and legumes). To maximize the detection of rare arable weeds, the weed survey was restricted to the edges of the fields, which are defined as the first cultivated meters adjacent to field margins (Marshall and Moonen, 2002). The sampling plots (2 m × 5 m) were established 80 m apart at the edges of the fields