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Different microhabitats have contrasting effects on the spatial distribution of tree regeneration density and diversity

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ABSTRACT

Spatial distribution of tree recruitment has been shown to be largely affected by microhabitats. If we are to preserve the distribution and abundance of tree regeneration in the face of environmental changes, we need to consider the microhabitats characterizing their recruitment process. We investigated the effect of type of microhabitat on the regeneration distribution of four tree species presence in the Zagros forests of western Iran. Regeneration density and diversity were found to be highly dependent on microhabitat. Regeneration density of *Quercus brantii* and *Ceracus microcarpa* was higher in heterospecific microhabitats. The highest density of regeneration occurred in the *Crataegus pontica* microhabitat, which covered 10.5% of the area. This study found that specific microhabitats affected the spatial patterns of tree regeneration in Zagros forests. Recruitment was restricted to those microhabitats under which environmental conditions constituted safe sites for regeneration. The *Crataegus pontica* microhabitat seems to have a major role in providing a safe site for regeneration in these forests. We suggest focusing restoration actions in *Crataegus pontica* microhabitats to better facilitate tree regeneration.

1. Introduction

The recruitment of tree species is a critical process in the population dynamics of forests and significantly influences the composition of forest communities (Carnicer et al., 2014). Quantitative analysis of tree regeneration may provide baseline information for conservation and management strategies (Singh et al., 2016). In general, the recruitment of new individuals is the outcome of a sequence of processes starting with seed production, dispersion and germination, to seedling emergence, establishment and growth. Each of these processes has specific probabilities of occurrence, and as such can affect plant life-cycle, species abundance, and distribution (Alagna et al., 2013). Spatial distribution of recruitment depends on the interaction of multiple abiotic and biotic factors. While spatial patterns of seed rain may depend on the location of parents and dispersal strategy, seedling distribution will be affected more by the presence of suitable microhabitats that control germination, emergence and seedling survival (Camarero et al., 2005). The spatial patterns of early recruitment have been shown to be strongly affected by the established vegetation found in microhabitats particularly in arid and semiarid habitats (Gómez -Aparicio et al., 2005a; Gómez -Aparicio, 2008). However, the ecological drivers of seedling growth and survival are diverse and can be affected by a variety of abiotic and biotic factors such as litter, light, micro topography, soil physical and chemical characteristics, seed arrival, herbivores and pathogens. All these factors are highly heterogeneous in space and vary at different scales, such as among geographical areas, among habitats in a region, or among microhabitats within a habitat (Gómez -Aparicio et al., 2005a).

The recruitment process is especially critical in arid and semiarid habitats, where biotic factors like seed dispersal, seedling survival, competition and facilitation can play a key role in plant regeneration (Cogoni et al., 2013). Natural regeneration in these forests is heavily limited at all stages, but particularly for seedlings, which are highly sensitive to micro-environmental conditions (Urbieta et al., 2008). The availability of major resources, including light, water and nutrients for seedlings, can change within a few meters (Quero et al., 2011) and may lead to the presence of microsites resulting in larger or faster growing seedlings (Harper, 1977; Grubb, 1977; Gonzalez-Rodriguez et al., 2011). Plant establishment in dry lands frequently depends on favorable conditions provided by other plants found in these micro-sites, partly because of the shade (Valladares and Pearcy, 2002). In other words, we could expect an intensification of the positive nurse-plant interactions that drive regeneration in arid and semiarid habitats (Gómez -Aparicio et al., 2008a). The nurse species that impart greater micro-environmental benefits, such as increasing shade, reducing summer-time radiation load, increasing soil moisture and reducing

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herbivory, have a higher facilitation impact on their understory plants (Jankju, 2013). Several authors have reported higher plant diversity, emergence and/or survival rate under the canopy of shrubs, compared to open areas (King, 2008; Gómez -Aparicio et al., 2008a; Soliveres et al., 2010; Soliveres et al., 2012). However, some studies have indicated that the beneficial effects of shade could be eclipsed by reduced soil moisture during dry years, which are expected to be more frequent in the most likely climate change scenarios in the Mediterranean region (Valladares and Pearcy, 2002; Valladares et al., 2008; Soliveres et al., 2013). To preserve the distribution and abundance of tree species in the face of environmental changes, we need to consider micro-sites that characterize their recruitment process (Gómez -Aparicio, 2008). However, little is known about the role of microhabitats on tree recruitment processes (Quero et al., 2011). Hence, an examination of the microhabitats under which environmental conditions constitute safe sites for seedling growth and survival is essential to understand the spatial structure and dynamics of plant populations (Gómez -Aparicio et al., 2005a).

Similar to other semi-arid areas around the world, Zagros oak forests in western Iran have been subjected to dramatic changes in forest regeneration, cover and structure in recent decades (Henareh Khalyani et al., 2012). The rapid decrease in forest area in Zagros suggests the possibility of similar dynamics behind critical shifts that have been found in other semi-arid areas of the world (Henareh Khalyani and Mayer, 2013). Zagros forests have critical national importance. These forests capture over one third of the country's annual precipitation, and are the headwaters for 40% of the country's rivers and streams which provide water to the dry central plateau of Iran (Jazirehi and Ebrahimi Rostaghi, 2003). Given the national and regional importance of Zagros forests, it is extremely useful for restoration management to identify the microhabitats that protect regeneration of trees, and to evaluate spatial distribution of tree regeneration.

We assessed the regeneration properties and diversity of the tree species in Zagros forests of western Iran. Our main goals were to: 1) analyze the tree regeneration properties, and 2) evaluate the effect of microhabitats on tree regeneration distribution. In this area, the tree species occupy contrasting microhabitat types, such as *Quercus brantii* sprout-clump, *Quercus infectoria* sprout-clump, *Crataegus pontica* trees, mixed and open microhabitat. These microhabitats enabled the analysis of tree species regeneration under different conditions. The following questions were addressed: (1) what are the tree species regeneration properties and diversity of regeneration in this area? and, (2) Can microhabitats be classified as low vs. high quality for overall regeneration or specific tree species? The results presented here provide information for improving our knowledge about the distribution of the tree species regeneration in these forests. With these data we could evaluate both the demographic status of this forest and evaluate the hypothesized relation between regeneration and microhabitat type to determine which are essential for conservation, restoration and management strategies.

2. Materials and methods

2.1. Study site

The study was conducted at the Gahvareh forests of western Iran (34° 18′11.2″- 34°18′27.5″N and 46°25′56″ – 46° 26′20.1″E). The climate is semi-arid, with precipitation concentrated in mid-autumn and winter, and hot, dry summers. Average annual rainfall is 440 mm with mean temperature of 11 °C. This area has been preserved by Forest, Rangeland and Watershed Management Organization of Iran from 2006 to improve the decaying rates of regeneration in Zagros forests.

2.2. Study species

Forests in this area are characterized by *Quercus brantii* Lindl, *Crataegus pontica* C. Koch, *Ceracus microcarpa* (C.A.M) Boiss and *Quercus infectoria* Oliv. *Quercus brantii* or Persian oak (covering more than 50% of the Zagros forest region in Iran) is the most important tree species of the Zagros (Sabeti, 2002). Both species of *Quercus* frequently exhibit a lack of regeneration. Seeds are dispersed mainly by gravity near the mother tree. Oak seeds are also dispersed by the Eurasian jay (*Garrulus glandarius* L.) that is found in the Zagros forest (Madge and Burn, 1994). A small fraction of the seeds can be dispersed by rodents. *Crataegus pontica* and *Ceracus microcarpa* occur as small, widely distributed subordinate trees in this region.

2.3. Regeneration sampling

We identified 5 microhabitat types in this area, a microhabitat being defined as a distinct homogeneous patch of habitat. The microhabitat types were: (1) *Quercus brantii* sprout-clump (2) *Quercus infectoria* sprout-clump (3) mixture of different species (mixed); (4) *Crataegus pontica* trees, and (5) open interspaces between woody vegetation. These microhabitats were the most abundant micro-sites in the study area. A systematic sampling grid was established for sampling the regeneration in the different microhabitat types. The starting point was chosen randomly. The initial installation consisted of 128 plots on 100 m spacing. Sampling density was intensified in the initial grid by installing 375 plots in one third of the study area, which reduced the spacing between plots to 20 m. Therefore, 504 plots 5 m × 5 m (microhabitat) were established. In each plot, after determining microhabitat type, tree regeneration (number of individuals of each tree species with height < 1.30 m (Tiscar-Oliver, 2015) was identified and counted. For each seedling observed, height and collar diameter were determined.

2.4. Statistical approach and methods

Species richness (Menhinick index) and diversity (Shannon H′index) were calculated for each plot (microhabitat) for the tree regeneration by using PAST version 1.39 (Palaeontological Statistics Software Package, 2006). The distribution of variables was analyzed with Q–Q plots (Timmer, 1998). All variables were log normally distributed; therefore a log-transformation (log (x + 1)) was carried out before further analysis (McDonald, 2014). Since our data did not reach perfect normal distribution, after transformation, we use Kruskal-Wallis tests followed by pair-wise Mann-Withney U tests for post hoc testing (Zar, 1999) in order to compare the variables, to answer our questions above with respect to regeneration. SPSS 17 Software was used for all non-parametric tests.

3. Results

3.1. Microhabitat mosaic

The dominant microhabitat type was *Quercus brantii* which covered 34.7% of the area. Mixed microhabitat occupied 26.3%, *Quercus infectoria* 14% and open microhabitats 13.8% of the total area. The *Crataegus pontica* microhabitat covered 10.5% of the area.

3.2. Regeneration properties

Mean density of regeneration was 3.35 (S.E. ± 0.18) individuals per plot with mean height of 60.55(S.E. ± 1.87) cm and mean collar diameter of 0.48 (S.E. ± 0.01) cm. These tree individuals were distributed among *Ceracus microcarpa* (3.06 ± 0.17, individual per plot), *Quercus brantii* (0.23 ± 0.03, individual per plot), *Quercus infectoria* (0.01 ± 0.00, individual per plot) and *Crataegus pontica* (0.06 ± 0.01, individual per plot). Collar diameter (0.50 ± 0.01, cm) and height (62.96 ± 1.85, cm) of *Ceracus microcarpa* were much higher than the other tree species (Table 1). The mean value of species diversity and