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Germination ecology of winter annual grasses in Mediterranean climates: Applications for soil cover in olive groves

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ABSTRACT

The sustainability of Mediterranean agroecosystems is threatened by several factors, soil erosion being the most important one due to poor management practices. Seeding native grasses for ground cover is an effective practice to protect soil and enhance ecosystem services, but the species to be used should be adapted to the climatic conditions and the particular requirements of each system. Here, we studied seed germination timing of six winter annual grasses: *Aegilops triuncialis*, *Anisantha madritensis*, *Anisantha rubens*, *Bromus hordeaceus*, *Hordeum murinum* and *Trachynia distachya*; with potential for ground cover in olive groves of the Iberian Peninsula. We conducted germination experiments under eight treatments of constant and alternate temperatures and seven treatments of water potential, and fitted hydro- and thermal-time models to assess possible responses of seed-based populations to regional climate. In all species, recently-harvested seeds showed high germination rates across a wide range of temperatures, while winter-stored seeds were highly tolerant to moisture stress. Our results suggest that environmental conditions rather than dormancy prevent germination of the studied species after dispersal. This germination pattern contrasts with the deep physiological dormancy described for winter annuals in temperate climates and desert regions, indicating a special adaptation of the studied populations for the long dry season in Mediterranean climates. We conclude that the regeneration ecology of these widely-distributed grasses makes them an excellent source of seeds for ground cover in Mediterranean woody crops.

1. Introduction

Mediterranean agroecosystems are threatened by soil erosion after decades of tilling and herbicide use (Laguna and Giráldez, 1990). As a response, conservation agriculture promotes a set of management practices such as “no tillage”, “reduced tillage” and “ground cover” to protect soil from erosion and to improve environmental quality (González-Sánchez et al., 2015). Ground cover is particularly recommended to prevent soil erosion in Mediterranean woody crops by covering the soil surface with inert matter, spontaneous vegetation, or sowing seeds (González-Sánchez et al., 2015). When sowing a ground cover, the chosen species should be adapted to the environmental conditions of the Mediterranean region, such as dry and hot summers and scarcity of water. Desirable traits for ground cover species in woody crops are: self-sowing capacity, low height, fast growth, superficial root development, capacity to capture and cycle nutrients, and persistence as dead matter on the ground (Barranco et al., 1998; García Torres et al., 2001; Rodríguez-Lizana et al., 2007). Especially important is that the ground cover develops during the winter season, providing effective soil protection and high biomass production, while not competing for water with the woody crop during summer (Alcántara et al., 2011).

Winter annual grasses (Poaceae) have most of the required traits for ground cover mixes in Mediterranean woody crops, because they are expected to produce dense vegetation cover and complete their life cycle before the dry season, thus avoiding water competition with the crops. However, successful use of these species will depend on the timing of population establishment, which in turn depends on the germination response of the seeds after they are sown. Seed germination is a complex physiological process subject to environmental cues, mainly temperature and soil moisture (Bewley et al., 2012; Baskin and

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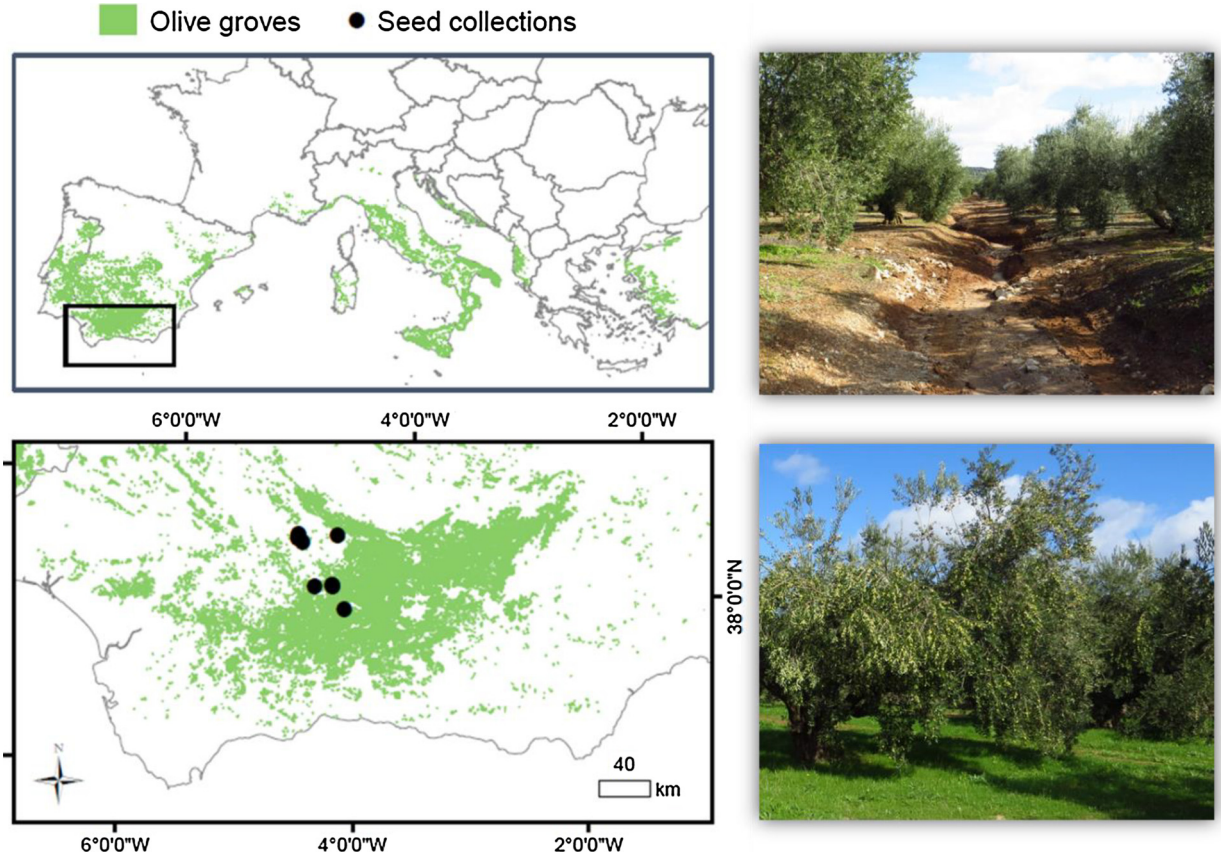

Fig. 1. Distribution of olive groves in Europe (except Greece, data from Corine land cover, European Union, 2006) coloured in green, and seed collection sites in the southern Iberian Peninsula (black dots). The photos show two examples of olive groves from Andalusia (Spain) with soil erosion and with a ground cover of native grasses. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Baskin, 2014). Seed germination is further regulated by seed dormancy, an inner seed property that regulates which environmental cues make the seed germinate (Vleeshouwers et al., 1995, Finch-Savage and Leubner-Metzger, 2006). Temperature is also a cue for germination timing, influencing the rate of germination in non-dormant seeds (Alvarado and Bradford, 2002) and interacting with soil moisture in seasonal climates (Itabari et al., 1993).

In general, winter annuals have a life cycle adapted to regeneration during the fall rainy season, with seeds that come out of dormancy during warm and dry conditions, and germinate when it is relatively cool and moist (Newman, 1963; Baskin and Baskin, 2014). Winter annual grasses generally have non-deep physiological dormancy which is released by summer high temperatures through dry-after-ripening (Baskin and Baskin, 2014), although fresh seeds of some species are non-dormant (Cheplick, 1998). It has been suggested that optimal germination temperatures of winter annuals are relatively low (around 16 °C) to prevent germination in summer, meaning that seeds will germinate when temperature decreases and available moisture increases with autumn rainfall (Cheplick, 1998). Although we expect these germination patterns in Mediterranean environments, studies on winter annual grasses have mainly focused on other biomes, especially in temperate regions (Probert, 1992; Baskin and Baskin, 2014; Werle et al., 2014) and deserts (Gremer and Venable, 2014; Lu et al., 2016). These studies reflect a high variation in germination timing and the level of seed dormancy across species and regions. Therefore it is still necessary to understand the germination responses of winter annual grasses in Mediterranean systems to predict their suitability for ground cover.

Here we investigate the seed germination ecology of winter annuals thriving in Mediterranean agroecosystems, focusing on six grasses with potential to be used as ground cover. Our main aim was to assess whether germination timing fits the life cycle required for a ground cover in Mediterranean olive groves of the Iberian Peninsula, a study system particularly threatened by soil erosion and loss of biodiversity. We hypothesized that seeds of Mediterranean winter annuals have (H1) non-deep physiological dormancy to prevent summer germination, (H2) high moisture germination requirements to delay germination until the start of the rainy season in autumn, and (H3) cold-cued germination to elicit autumn germination. To test these hypotheses, we collected seeds from six native species in an important olive region from Andalusia (Spain) characterized by a typical Mediterranean climate with long dry summers. We used laboratory experiments to mimic the temperature regime in four different seasons of the study area and measured seed germination in response to these regimes. Finally, we assessed how the germination timing of these species matched seasonal temperatures in the study region, to determine their suitability to be used as ground cover in Mediterranean agroecosystems.

2. Material and methods

2.1. Study species

The criteria for choosing the study species were those to meet the requirements of native seeds for the management of a ground cover in olive groves: self-sowing, early germination. short height, fast growth, adaptation to the rainy season, superficial root development, capacity to capture and cycle nutrients, and persistence of the dead plant matter on the ground (Barranco et al., 1998; García Torres et al., 2001; Rodríguez-Lizana et al., 2007). In 2015 we conducted several field surveys to identify candidate winter annuals and selected six grasses