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Germination of an obligate seeder (*Ulex parviflorus*) and consequences for wildfire management

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ABSTRACT

In fire-prone ecosystems, reducing the risk of wildfire is generally attempted through vegetation clearing using controlled fires or, less often, mechanical techniques. Management practices, however, can be poorly efficient when the disturbances they introduce install environmental conditions that are similar to the ones under which the undesirable species evolved. *Ulex parviflorus* is a Mediterranean obligate seeder with physical dormancy forming large amounts of highly combustible standing necromass. In the present study, combining field and laboratory experiments, we determined the seedling recruitment of this species under different management practices (burning, mechanical clearing, slash/no slash on soil surface), we measured the environmental conditions (temperature, light, and moisture) enforced by these practices and we tested their individual and combined impact on germination in order to determine the most appropriate control method for this species. Germination is low under intact canopies, but it is strongly stimulated by both brush-chipping and fire. This is partly related to the inhibiting effect of the low red:far-red ratio of the light filtered by the canopy which is removed by brush-chipping and fire. The other factor involved is moderate heat, either fire-generated or resulting from solar radiation on bare soil, which breaks seed coat impermeability. Indeed exposing seeds on bare soil in summer resulted in a significant increase in their germination capacity and germination was reduced when the brush chips remained on the soil. Moisture fluctuations did not enhance germination. The summer heat impact affects management practices. When the brush-chipping treatment occurred before summer, the germination flush appeared the following autumn, but when the treatment occurred after summer, the germination flush did not appear until the autumn of the subsequent year, when interspecific competition with regenerating vegetation is likely to be more intense. We demonstrated that brush-chipping, especially when done after summer, is a better technique than fire for controlling *U. parviflorus* because it creates environmental conditions that are less favourable for its germination. This technique also has the potential to favour late-successional species less vulnerable to fire. By combining fuel reduction and land restoration, this technique is useful to the sustainable management policies that need to be developed.

1. Introduction

Wildfires constitute a serious risk in many regions of the world, and their frequency is expected to increase as a result of climate change and land abandonment (fuel accumulation), in particular in Mediterranean regions (Piñol et al., 1998; Cramer, 2001; Pausas, 2004). Vegetation control for reducing fuel loads in forest and shrubland ecosystems is often applied to decrease the fire risk and improve the probability of successful fire control by reducing fire intensity.

Several management techniques have been developed to control undesirable species, including mechanical clearing, herbicides, fire, grazing, biological control agents or a combination of these (Paynter and Flanagan, 2004; Buckley et al., 2004). However, despite the stressfulness of these management techniques, the fact that natural selection in many species occurred under drastic disturbance regimes (Pickett and White, 1985) can reduce the effectiveness of these efforts. This is particularly the case in biomes where fire has been part of the selective forces shaping biodiversity. Such species have developed very effective regenera-

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tion mechanisms, which are triggered by the environmental conditions associated with fire. Nevertheless, Zedler and Zammit (1989) pointed out that few of these conditions are specific to fire (very high temperatures, ash or charcoal covering) while most are shared with other disturbances, including management practices (changes in light intensity and quality, temperature, moisture, competition). Thus, fuel reduction management could have the counterproductive effect of facilitating the germination of undesirable species. For a successful vegetation management programme, understanding the ecological processes involved in recruitment are of key importance to generate unfavourable opportunities for undesirable species regeneration (Freckleton, 2004).

Ulex parviflorus Pourr., Mediterranean gorse, is a shrub of the Fabaceae family found all along the Mediterranean coasts (and up to 100 km inland) of Southwestern Europe and North Africa (Tutin et al., 1964–1980). It is an obligate seeder with a physical exogenous dormancy on the seed (Baeza and Vallejo, 2006), which develops massively after land abandonment and fire and can constitute the dominant species of dense thickets, as is the case in Southern Spain. When senescence occurs (after 20–25 years), these stands constitute large amounts of highly combustible standing necromass (Baeza et al., 2006). Management strategies to control the extension of *U. parviflorus* are now being studied and applied; among these, controlled fires and clearings are the most common (Lloret and Vilà, 1996; Baeza et al., 2002b). However, experimental burning and brush-chipping have shown the difficulty of controlling *U. parviflorus* due to its massive regeneration through seed germination (Baeza, 2001). The elimination of existing vegetation and the high temperature generated in the fire can scarify the seed coat and break the dormancy of seeds stored in the soil (Baskin and Baskin, 1998). Similar environmental problems are caused on a larger scale by other leguminous species like *Ulex europaeus* L. and *Cytisus scoparius* (L.) Link, both of which are native to Europe and are now regarded as noxious weeds in New Zealand, Chile, Hawaii, North America and Australia (Rees and Hill, 2001; Sheppard et al., 2002).

Leguminous species have an impermeable seed coat that imposes physical dormancy on the seed; to germinate the water-impermeable layer must become permeable (Baskin and Baskin, 1998). In Mediterranean-type ecosystems, heat from fire has been directly correlated with seedling recruitment because high temperatures can break hard seed coat dormancy, making seeds permeable and ready to germinate under favourable environmental conditions. This temporal sequence indicates that the environmental factors involved in seed dormancy breakage may differ from those involved in germination (Thompson et al., 2003). In nature, fire is the most extreme example of temperature overcoming dormancy in hard-seeded species (Auld, 1986); other factors associated with temperature could also be related to dormancy loss (Ooi et al., 2006). Under field conditions, combined temporal sequences of high temperatures in summer followed by moist conditions in autumn occur seasonally. By uncoupling these seasonal effects management programmes may be able to delay the emergence flush in species with physical dormancy and improve control efficiency.

In this paper we analyse the germination conditions of a largely undesirable shrub in relation to its current management practices and we discuss the suitability of these practices. We study (i) the *in situ* germination of *U. parviflorus* after different management treatments, (ii) the environmental soil surface conditions created by these treatments and (iii) the germination requirements of the seeds in controlled conditions. We then compare the relative efficiency of fire-specific and general-disturbance germination clues and discuss the techniques used for managing this species in the light of its germination ecology.

2. Material and methods

2.1. Study area and sites

The study was conducted in the Mariola and Aitana interior mountains in the northwest of the Alicante province, Spain. The typically Mediterranean climate is characterised by a mean annual precipitation of 495 mm (Onil, 38° 39′N, 0° 40′W, 800 m above sea level, 40 km from the sea) with a summer drought from mid-May to mid-September. The mean temperature is 14.5 °C with mean monthly temperatures ranging from 7.5 °C in January to 23.5 °C in July. Four sites (Alcoy, Bañeres, Castell and Onil), were chosen within a 40 km distance. Their climatic conditions, bedrock (marl) and soil (deep loamy *Calcaric Cambisol*, FAO 1998) are similar. All 4 sites were cultivated terraces abandoned after the Spanish Civil war (1939). They were covered with Aleppo pine (*Pinus halepensis* Mill.) forests until a wildfire in 1985 (Alcoy and Onil) or 1991 (Bañeres and Castell). At the beginning of the field experiments (1994), the shrubland vegetation was dominated by *U. parviflorus* and to a lesser extend by other obligate seeders such as *Cistus albidus* L. and *Rosmarinus officinalis* L. A few isolated individuals of woody resprouters were present (*Quercus coccifera* L., *Juniperus oxycedrus* L. and *Rhamnus alaternus* L.) as well as a few small isolated individuals of *P. halepensis*. The herbaceous layer, covering approximately 70% of the ground, was dominated by *Brachypodium retusum* (Pers.) Beau.

2.2. Field experiments

The four sites were part of a larger experiment designed to study the impact of successional stage and fuel load on fire behaviour and its implications for using control burning or clearing to reduce wildfire risk (Baeza et al., 2002b). In each site, three treatments were applied in May 1994, each on a single 1000 m^2 plot: control, brush-chipping (slash remaining on the soil) and burning. Once a month until January 1996, *U. parviflorus* seedlings occurrence was recorded in 20 randomly distributed 0.5 m × 0.5 m sub-plots within each plot.

In Onil, three 1000 m^2 plots were brush-chipped for a fuel-break experiment in September 1996. The effect of keeping the chips on the ground (slash with 100% cover) or removing them (no slash, bare soil) on *U. parviflorus* germination was tested. In each plot, the chips were removed in five randomly distributed 1 m × 1 m sub-plots and kept in five other randomly distributed 1 m × 1 m sub-plots. *U. parviflorus* seedling occurrence was recorded in all these sub-plots from October 1996 until May 1998.

In Onil, the impact of seed exposure to soil surface summer conditions was tested using seeds collected in June 2001 from mature fruits in Bañeres and in Castell. For each seed origin, 20 sets of 50 seeds were enclosed in bags made with nylon mesh (0.5 mm). Five sets were kept as control while fifteen were put on the bare ground of a fuel-break on July 1, 2001. Five sets were removed after 30 days, five sets after 60 days and the remaining 5 sets after 90 days. Soil surface temperature was measured and recorded every hour with a temperature probe (Hobo® Event, Onset Computer Corporation, Bourne MA, US). Each set of seeds was then put in a Petri dish on filter paper and enclosed in a germination chamber (12 h light at 22 °C, 80% moisture and 12 h dark at 20 °C and 85% moisture). Filter paper moisture and seedling germination were checked every other day for 60 days.

These field experiments suggested that fluctuations in soil temperature and moisture as well as heat generated by fire or change in light quality due to green leaves removal could stimulate *U. parviflorus* germination. These physical characteristics were then documented in the field before testing their isolated or