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Post-fire germination: The effect of smoke on seeds of selected species from the central Mediterranean basin

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Abstract

In regions with a Mediterranean-type climate wildfires are a frequent occurrence: in such environments fire tolerant/favoured species are frequently encountered. In the Mediterranean basin, many species of fire prone habitats are resprouters while others are known to germinate after fire. Fire causes an enhancement of seed germination in many species from fire prone habitats in the other regions with a Mediterranean-type vegetation such as Western Australia, California and South Africa. Seeds of a number of these species are stimulated to germinate by the smoke generated from burning of plant material in either an aerosol or aqueous form. However, for species from the Mediterranean basin the role of smoke in germination is poorly known, despite the fact that in the field many species seems to be encouraged to germinate after fire. We examined the germination of 10 species native to the Mediterranean basin that were treated with aerosol smoke. Some species were from fire prone habitats while others were not. In relation to the controls, increased germination occurred in three of the species (e.g. *Cistus incanus*), three had more rapid germination but no total increase (e.g. *Rhamnus alaternus*), two showed reduced germination (e.g. *Asphodelus ramosus*) and two exhibited no difference in germination (e.g. *Clematis flammula*). There was additionally no consistent pattern of germination behaviour depending on the habitat from which the species came. Comparison is made between the results of this study and those of other studies on seed germination response to heat and smoke in other areas of Mediterranean-type climate. An understanding of the importance of fire in relation to other disturbances in the vegetation dynamics in the Mediterranean basin needs to be clarified by further detailed studies of the effect of heat and smoke products on seed germination of Mediterranean species. Outcomes of further research, also on a broader range of species, would have important impacts also for conservation, environment management, horticulture and ecosystem restoration.

Keywords: Mediterranean basin; Smoke; Chapparal; Fynbos; Kwongan; Matorral; *Erica*; *Juniperus*

1. Introduction

Special germination cues (other than the presence of water) are widely spread throughout the world's flora. As plants have only limited ability to select where they grow, having a mechanism which improves chances of successful seedling establishment can be evolutionarily advantageous. Using a ubiquitous predictive cue for suitable establishment conditions is likely to be more efficacious than a very specialised one. For example, for a plant species which utilises animal dispersal to locate a suitable germination site the species may be at risk of local extinction if the animal disperser disappears from the area where the plant grows (e.g. mistletoes). Alternatively the more general cue of red light is a suitable dormancy breaker in seeds which might be shaded by overstorey plants so when they receive more red than far red light conditions are suitable for germination (Ray et al., 1983).

Other cues for germination are cold followed by warmer temperatures, heat and rainfall sufficient to remove seed coat chemicals that inhibit germination. Another ubiquitous type of germination stimulant is provided by fire. The cue of fire products, such as heat, chemical stimulants and changes in the microsites (Baskin and Baskin, 1998) indicates the clearance of adult plants from a site. The area is then ready for relatively competition-free establishment of seedlings in an environment that may also have slightly higher nutrient levels, particularly on the soil surface, than in an undisturbed system. This type of fire-related cue to germination is found in many species from Mediterranean-type climates (Keeley and Bond, 1997).

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South-Western Australia, the Cape of South Africa, coastal California, mid latitude Chile and the Mediterranean basin are the five mediterraneoid geographic regions characterised by moderate mean annual temperatures, winter maximum rainfall and a relatively dry, hot summer. Climate is considered to have been a significant selective force in the development of vegetation in mediterraneoid regions and the similarity/convergence of vegetation structure and plant forms in areas of Mediterranean-type climate has been examined by many authors (Specht, 1979; Cowling and Campbell, 1980; Pignatti and Pignatti, 1985; Pignatti et al., 2002). However, despite the many similarities in vegetation and plant form it has also been considered that the similarities are mainly superficial and that many differences of detail tend to outweigh the general similarities (Barbour and Minnich, 1990).

Many of the dominant species in the drier parts of the Mediterranean-type environments (<600–700 mm/a) are strong resprouters after defoliation by any disturbance, while others have no ability to survive severe damage to the adult, such as occurs in a fire, and rely entirely on seed for regeneration. In South African fire-dependent plant communities, fynbos, fire regime plays an important role in germination (Keeley and Bond, 1997). In many Australian species of the kwongan, fire and appropriate moisture levels are highly favoured as the two most important germination cues, ensuring germination occurs under favourable environmental conditions (Bell, 1999). In Californian chaparral there is a rich flora with different mechanisms for cuing germination to post-fire conditions (Keeley, 1991). In all these regions, where many species have evolved barriers to germination that are normally overcome by fire-related cues (Keeley and Fotheringham, 1997), fire is an important component in the seed bank dynamics with up to 40% of species having enhanced germination following fire. In Chilean matorral, on the other hand, fire-stimulated seed germination as only been shown on few species (Segura et al., 1998) so, at present, there are no evidences of fire being an essential enhancing agent for seeds germination in this region. In the Mediterranean basin, many species of fire prone habitats are resprouters (Naveh, 1975; Piotto et al., 1999), some geophytes sprout and flower (Grove and Rackman, 2001), while only some taxa, e.g. *Cistus*, are known to germinate predominantly after fire (Trabaud and Oustric, 1989; Ojeda, 2001).

One ubiquitous factor in these mediterraneoid areas is the importance of fire in the vegetation dynamics of the regions (di Castri, 1981). There has been considerable debate over the degree to which other environmental factors responsible for the death of above ground plant parts such as grazing, landslides and drought have contributed to the evolution of the flora which now has a number of fire resistant traits (Naveh, 1994; Pignatti and Pignatti, 1999; Ojeda, 2001; Grove and Rackman, 2001; Ladd et al., 2004). However it is still considered that there is ''a striking evolutionary adaptation'' of this system to fire (Naveh, 1999).

Smoke is a by-product of fire and it is used to break the dormancy of seeds of many species from some of the mediterraneoid regions and has been studied in detail over the last 10 years. A butenolide compound has been recently isolated from the cocktail of smoke chemicals and shown to be as effective as smoke, in general, in enabling germination of seeds which would normally have no or very low germination without smoke treatment (Flematti et al., 2004; van Staden et al., 2004). While fire is ubiquitous in Mediterranean-type climates smoke enhanced germination is most frequent in the Cape of South Africa (de Lange and Boucher, 1990; Brown et al., 1993, 1994) and Southern Australian species (Dixon et al., 1995; Roche et al., 1997a,b; Enright et al., 1997; Read and Bellairs, 1999), less so in Californian species (Keeley and Fotheringham, 1997, 1998); in Chilean species, to our knowledge, the effect of smoke on germination has never been accurately investigated. For Mediterranean basin species the role of smoke in seed germination has only recently started to be examined (Pérez-Fernández and Rodríguez-Echeverría, 2003) and is still not fully understood, although smoke is a specific feature that more than others could be rigorously related to fire.

In South Africa and Western Australia, smoke is currently used in restoration projects with native species from nursery production to direct application on site for significant improvement in recruitment from the soil seed bank (Roche et al., 1997b; Brown and van Staden, 1998; Crosti et al., 2003)

2. Aim

To examine the effect of aerosol smoke on the germination of a selected range of species typical of the Mediterranean basin plant communities. The null hypothesis was that smoke had no effect on germination of seed of the selected species.

3. Materials and methods

3.1. Seeds

3.1.1. Seed collection

The species selected were representative of maquis which is frequently burnt and other vegetation which rarely experiences fire. Seeds of most of the species were purchased from accredited commercial collectors while others were self hand-harvested.

3.1.2. Seed viability

The presence of white, healthy and intact embryo was determined through the cut test method. Viability was evaluated from three replicates of 30 seeds each and only species with seed viability higher than 15% were used in the experiment. Although initially 25 selected species were examined, only 10 had the acceptable viability and minimum germination values applicable for the experiment. Minimum germination was set at >5%.

3.1.3. Seed treatment

The ex situ experiment was undertaken at the Kings Park and Botanic Gardens, Perth, Western Australia (*'ex altera parte*