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SHORT COMMUNICATION

Drought, salinity and heat differently affect seed germination of *Pinus pinea*

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Abstract Drought, salinity and forest fires are adverse abiotic factors responsible for the failure of plant regeneration in the Mediterranean regions. The objective of this study was to evaluate *Pinus pinea* seed germination in response to heat, osmotic and salinity stress. Separate experiments were conducted, using polyethylene glycol (PEG) as an osmotic agent to reproduce drought stress, and sodium chloride (NaCl) and diluted seawater as salinizing agents to simulate salinity stress. Different temperatures were used to reproduce the effects of different fire regimes. Seed germination and the activities of the main enzymes involved in *Pinus* seed reserve utilization (glyoxylate cycle enzymes) decreased with increasing PEG, NaCl and seawater concentrations. Seawater appears to be the least toxic salinizing agent on *Pinus pinea* seed germination. The present study indicates that the germination of *Pinus pinea* seeds is influenced by the concentrations and even more by the nature and interactions of the ions present in the solutions. As regard heat treatments, the maximum germination percentage (80%) was obtained at 80°C and short exposure time (3 min). Increasing exposure time and temperature led to the germination percentage progressively decreasing.

Keywords Glyoxylate cycle · Heat treatment · Osmotic stress · *Pinus pinea* · Salt stress

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Introduction

The arid or semiarid climate of the Mediterranean region, the progressive salinization of land and the increased summer forest fires have been indicated as the most severe problems affecting seed germination and plant growth (Habrouk et al. 1999; Núñez and Calvo 2000; Rodríguez et al. 2005; Pausas 2006).

Salts [sodium chloride (NaCl), magnesium chloride, calcium chloride, etc.] that are natural elements of soil are essential plant nutrients up to 4.5 dS/m (50 mM), but when present in the soil in excessive concentrations can affect plant growth. The most detrimental effect of salinity is due to the presence of NaCl that affects seed germination and plant growth, either creating an osmotic potential (Soltani et al. 2006) or by ion specific damage (Ali et al. 2001). Salinity and osmotic stress both limit plant growth, affecting various metabolic processes such as photosynthesis, protein synthesis, respiration, nitrogen assimilation and phytohormone turnover (Muscolo et al. 2003; Rai and Rai 2003). The responses of plant species to salinity and osmotic stress in terms of germination and growth are the ultimate expression of several interacting physiological and biochemical parameters.

The Mediterranean regions with adverse climatic and edaphic conditions are characterized by a high proportion of *Pinus* species (Keeley and Zedler 1998; Court-Picon et al. 2004; Rodney 2004). Among them, *Pinus pinea* (Italian stone pine) is widely distributed all over the Mediterranean basin. Therefore, its conservation is one of the most important objectives of current management strategies.

In natural field conditions, stress may be transient and the capacity of the plant to achieve its whole cycle is directly related to its ability to recover after stress period.