Universidad Politécnica de Cartagena

Technology and Knowledge Transfer e-Bulletin

Vol. 2 No. 3 2011

FIRE RESILIENCE AND FOREST RESTORATION IN MEDITERRANEAN FIRE-PRONE AREAS

D. Moya [2*], J. De las Heras [2], P. Ferrandis [2], J. M. Herranz [2] and J. J. Martínez-Sánchez[1]

[1]Departamento de Producción Vegetal, Unidad Asociada al CSIC de "Horticultura Sostenible en Zonas Áridas" (UPCT-CEBAS), Universidad Politécnica de Cartagena, Paseo Alfonso XIII, 48, 30203 Cartagena, Spain.

[2]Departamento de Producción Vegetal y Tecnología Agraria. Universidad de Castilla-La Mancha. Campus Universitario, ETSI Agrónomos. 02071 Albacete, Spain

[*]Corresponding author to whom more information request should be addressed (e-mail: Daniel.Moya@uclm.es).

Additional keywords: wildfire, seed germination, soil seed bank*; Pinus halepensis* Mill.*, Pinus pinaster* Aiton*, Cistus*, post-fire Management, fire ecology

INTRODUCTION

Mediterranean ecosystems are of importance worldwide because they are biodiversity hot spots. In these areas, forest fires have been modelling the landscape since the Pleistocene Era. Consequently, plant communities inhabiting this fire-prone area have developed adaptive traits (e.g. serotiny) or life-history strategies to persist, exhibiting a high degree of survival or recovering after frequent fires or other disturbances, such as severe drought. In general, this implies high resilience, but in recent years aridity and fire dynamics have been increasing due to global climate change, which has strongly affected the Mediterranean Basin. These changes are inducing higher risks of soil loss and lower plant productivity in the long term, which influences the resilience of the community present before the disturbance. Some species are pirophytes (fire adapted), such as *Cistus* sp. (Ferrandis *et al.,* 1999a), or pirophyles (fire dependant). *Pinus halepensis* Mill. and some populations of *Pinus pinaster* Aiton have been catalogued as pirophylous species. They are not promoted by fire (Martínez-Sánchez *et al.*, 1996) but show colonizer behavior in the absence of fire (Ayari *et al.,* 2011).

The main four components of resilience are elasticity (recovery rate), amplitude (fire severity inducing no recovery), malleability (differences from the previous state) and damping (oscillation of ecosystem parameters). If the plant community does not recover after disturbance or natural characteristics do not achieve forest planning objectives, restoration and stand improvement through forest management are important choices for lowering the aridity risk (Figure 1).

Figure 1. Aleppo pine stand burned in summer, 2009, in southeastern Spain

Universidad Politécnica de Cartagena

Technology and Knowledge Transfer e-Bulletin

Vol. 2 No. 3 2011

EFFECT OF FIRE ON SEEDS

Soil is not a good heat conductor, so during a forest fire the heating rate decreases with increasing soil depth. In the Mediterranean Basin, the seed banks in the soil are usually accumulated in the upper layers, implying their transient nature and a strong influence of fire (Ferrandis *et al.,* 2001a).

Regarding soil seed banks, the genus *Cistus* is an obligate seeder species with a broadly range in the Mediterranean area of central and eastern Spain. Usually, *Cistus* species are part of the community in the form of living plants, but they also have seed banks persistent over the long term. Some species, such as *Cistus ladanifer* and *C. salvifolius*, have shown dormancy in the absence of fire, although low and medium intensity fires do not influence germination values (Ferrandis *et al.,* 1999c). In general, recurrent wildfires have a selective impact on the soil seed bank species; those with transient seed reserves are eliminated and those species with persistent, buried seed reserves tend to remain in the soil after the passage of fire (Ferrandis *et al.,* 1999b).

Pinus halepensis and some populations of *P. pinaster* have shown adaptation to fire by storing seeds in closed, grey (serotinous) cones in the canopy. Seed germination is not improved by heating, although seeds from both species show fire resistance to severe fires (Martínez-Sánchez *et al.,*1995). Fire resistance is a result of anatomical characteristics of the seed coat with high insulation properties, such as wax and cutine cells covering the seed coat and high Si and Ca concentrations in the seed shell. Insulation properties were magnified in seeds in serotinous cones (Salvatore *et al.,* 2010). Serotinous cones are efficient heat insulators according to anatomical and morphological characteristics, such as compressed, thicker scales with multiple layers (Moya *et al.,* 2008c) (Figure 2).

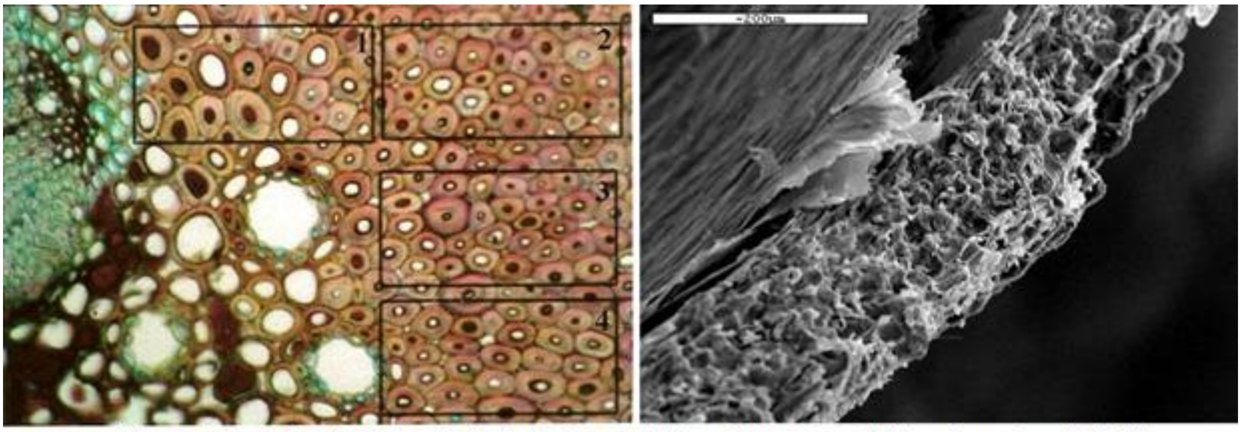

Figure 2. Anatomical and morphological characteristics of pine cones (left) and seed coats (right) related to insulating properties

POST-FIRE REGENERATION AND DYNAMICS

Several studies have examined floristic composition over the short term in post-fire Mediterranean ecosystems to describe community recovery (Figure 3). Results show the highest abundance and plant cover in the first 2 years after the fire, followed by a decrease in the long term until they reach characteristics similar to before the disturbance, according to the ‘‘initial floristic model’’ (Ferrandis *et al.,* 1996; Herranz *et al.,* 1996; Moya *et al.,* 2009). In a very short time, the main contribution to the natural recovery of a Mediterranean plant community is from the resprouters (covering half of the area in the first weeks or months after the fire). In the middle-long term, seeders gain importance and dominate the surface the first or second year after the fire (Trabaud *et al.,* 1997). However, natural recovery is influenced by many factors, such as stand structure, weather conditions or fire severity (Ferrandis *et al.,* 2001b). In south-eastern Spain (semiarid ombroclimate), plant regeneration and recruitment after fire depends highly on the weather conditions of the first year (Martínez-Sánchez *et al.,* 1998) but also greatly influences seedling mortality in the first two or three years, determining the density of sapling survival (Herranz *et al.,* 1997). On the ground, bryophyte communities play a significant protective role in burned areas by preserving nutrient and soil losses, although the recovery model after fire differs from higher plants (Martínez-Sánchez *et al.,* 2000).

Figure 3. Adaptive traits to recover after fire. Obligate seeders develop serotiny and release seeds after fire (left) and resprouters grow shoots just few days after fire (right)

Eventually, natural regeneration can be excessive, depending on site quality, leading to grossly overstocked areas covered by dense clumps of small trees and thickets which are competing for space and nutrients (dog-hair formation) and are delayed in reaching maturity (Moya *et al.,* 2007; Moya *et al.,* 2008a). In these cases, there is low light, water and nutrient availability due to inter- and intraspecific competition (Martínez-Sánchez *et al.,* 2003).

EARLY POST-FIRE MANAGEMENT

Post-fire emergency actions are focused on protecting high risk areas by preventing erosion, flooding and soil losses. Salvage logging is one of the most common forest management emergency actions after fire in the short-term, but its ecological effects implications are not well known. Some studies found that salvage logging did not positively influence seedling survival, leading to a sapling deficit in natural recovery and forest development, especially when there is a low seedling density (Martínez-Sánchez *et al.,* 1999). To reduce interspecific competition, early shrub clearing treatments (before the 2nd year after the fire) are recommended to increase sapling density of the main tree species. This silvicultural tool induces lower sapling mortality and improves the growth of the selected species when carried out early, especially in areas where the initial post-fire pine sapling density is not high enough to be successful in the early, critical, competitive period (De las Heras *et al.,* 2001). Similarly, early silvicultural treatments are advised for improving the stand (Figure 4), although the optimum depends on the species and site quality (Moya *et al.,* 2008b; Lopez-Serrano *et al.,* 2010). The silvicultural treatments studied include thinning intensity, the age at which to carry out thinning and clearing, pruning (including height), shrub clearing and the effects of combined treatments, in the short and middle term (De las Heras *et al.,* 2001; De las Heras *et al.,* 2007; Moya *et al.,* 2008b). The benefits related to early silvicultural treatments in Aleppo pine stands have been related to improved growth (in height and trunk diameter) in addition to an increase in canopy seed bank (De las Heras *et al.,* 2007). Earlier arrival at the mature phase, measured by the reproduction stage, certain structural patterns and diversity parameters, has also been demonstrated (Moya *et al.,* 2009).

Figure 4. Unmanaged Aleppo pine stands ten years after fire (left) and treated stands with intensive thinning five years after fire (right)

Vol. 2 No. 3 2011

LITERATURE CITED

AYARI, A., MOYA, D., REJEB, M. N., BEN MANSOURA, A., ALBOUCHI, A., DE LAS HERAS, J., FEZZANI and T., HENCHI, B. (2011). Geographical variation on cone and seed production of natural *Pinus halepensis* Mill. forests in Tunisia. *Journal of Arid Environments*, 75: 403-410.

DE LAS HERAS, J., MARTÍNEZ-SÁNCHEZ, J. J., GONZÁLEZ-OCHOA, A. I., FERRANDIS, P. and HERRANZ, J. (2001). Establishment of *Pinus halepensis* saplings following fire: effects of competition with shrub species. *Acta Oecologica*, 23: 91–97

DE LAS HERAS, J., MOYA, D., LOPEZ-SERRANO, F. R. and CONDES, S. (2007). Reproduction of postfire *Pinus halepensis* Mill. stands six years after silvicultural treatments. *Annals of Forest Science*, 64 (1): 59-66.

FERRANDIS, P., HERRANZ, J. M. and MARTÍNEZ-SÁNCHEZ, J. J. (1996). The role of soil seed bank in the early stages of plant recovery after fire in *Pinus pinaster* Forest in SE Spain. *International Journal of Wildland Fire*, 6(1): 31-35.

FERRANDIS, P., HERRANZ, J. M. and MARTÍNEZ-SÁNCHEZ, J. J. (1999a). Effect of fire on hard-coated *Cistaceae* seed banks and its influence on techniques for quantifying seed banks. *Plant Ecology,* 144: 103-144.

FERRANDIS, P., HERRANZ, J. M. and MARTÍNEZ-SÁNCHEZ, J. J. (1999b). Fire impact on a maquis soil seed bank in Cabañeros national Park (central Spain). *Israel Journal of Plant Sciences*, 47: 17-26.

FERRANDIS, P., MARTÍNEZ-SANCHEZ, J. J., AGUDO, A., CANO, A. L., GALLAR, J. J. and HERRANZ, J. M. (1999c). Presencia de especies del género *Cistus* L. (Cistaceae) en el banco de semillas del suelo en el pastizal de la raña del parque nacional de Cabañeros. *Investigacion Agraria: Sistemas y Recursos Forestales*, 8(2): 361-376.

FERRANDIS, P., HERRANZ, J. M. and MARTÍNEZ-SÁNCHEZ, J. J. (2001a). Response to fire of a predominantly transient seed bank in a Mediterranean weedy pasture (eastern-central Spain). *Ecoscience*, 8(2): 211-219.

FERRANDIS, P., DE LAS HERAS, J., MARTÍNEZ-SÁNCHEZ, J. J. and HERRANZ, J. M. (2001b). Influence of a low-intensity fire on a *Pinus halepensis* Mill. forest seed bank and its consequences on the early stages of plant succesion. *Israel Journal of Plant Sciences*, 49: 105-114.

HERRANZ, J. M., MARTÍNEZ-SÁNCHEZ, J. J., DE LAS HERAS J. and FERRANDIS, P. (1996). Stages of plant sucession in *Fagus sylvatica* L. and *Pinus sylvestris* L. forests of Tejera Negra Natural Park (Central Spain) three years after fire. *Israel Journal of Plant Sciences*, 44: 347-358.

HERRANZ, J. M., MARTÍNEZ-SÁNCHEZ, J. J., MARÍN, A. and FERRANDIS, P. (1997). Post-fire regeneration of *P. halepensis* Miller in a semi-arid area in Albacete province (Southeastern Spain). *Ecoscience*, 4: 86-90.

LOPEZ-SERRANO, F. R., DE LAS HERAS, J., MOYA, D., GARCIA-MOROTE, F. A. and RUBIO, E. (2010). Is the net new carbon increment of coppice forest stands of *Quercus ilex* ssp *ballota* affected by post-fire thinning treatments and recurrent fires? *International Journal of Wildland Fire*, 19 (5): 637-648.

MARTÍNEZ-SÁNCHEZ, J. J., MARÍN, A., HERRANZ, J. M., FERRANDIS, P. and DE LAS HERAS, J. (1995). Effects of high temperatures on germination of *Pinus halepensis* Mill. and *Pinus pinaster* Ait. subsp pinaster seeds in southern Spain. *Vegetatio,* 116: 69–72.

MARTÍNEZ-SÁNCHEZ J. J., HERRANZ, J. M., GUERRA, J. and TRABAUD, L. (1996). Natural re-colonisation of *Pinus halepensis* Mill. and *Pinus pinaster* Aiton in burnt forests of the Sierra de Alcaraz-Segura mountain system (SE Spain). *Ecologia Mediterranea*, 22: 7-24.

MARTÍNEZ-SÁNCHEZ, J. J., HERRANZ, J. M., GUERRA, J. and TRABAUD, L. (1998). Influence of fire on plant regeneration in *Stipa tenacissima* L. community in Sierra Larga mountain range (SE Spain). *Israel Journal of Plant Science*, 45: 309-316.

Universidad Politécnica de Cartagena

Technology and Knowledge Transfer e-Bulletin

Vol. 2 No. 3 2011

MARTÍNEZ-SÁNCHEZ, J. J., FERRANDIS, P., DE LAS HERAS, J. and HERRANZ, J. M. (1999). Effect of burnt wood removal on the natural regeneration of *Pinus halepensis* after fire in a pine forest in Tus valley (SE Spain). *Forest Ecology and Management* 123: 1–10.

MARTÍNEZ-SÁNCHEZ, J. J., FERRANDIS, P., DE LAS HERAS, J. and HERRANZ, J. M. (2000). Functioning and dynamics of plant communities in central and southern Spain. In: L TRABAUD, L. (ed), Life and Environment in the Mediterranean, WIT Press, *Southampton,* pp. 87–128.

MARTÍNEZ-SÁNCHEZ, J. J., FERRANDIS, P., TRABAUD, L., GALINDO, R., FRANCO, J. A. and HERRANZ, J. M. (2003). Comparative root system structure of post fire *Pinus halepensis* Mill. and *Cistus monspeliensis* L saplings. *Plant Ecology*, 168(2): 309-320.

MOYA, D., ESPELTA, J. M., VERKAIK, I., LOPEZ-SERRANO, F. R. and DE LAS HERAS, J. (2007). Tree density and site quality influence on *Pinus halepensis* Mill. reproductive characteristics after large fires. *Annals of Forest Science*, 64 (6): 649-656.

MOYA, D., ESPELTA, J. M., LOPEZ-SERRANO, F. R., EUGENIO, M. and DE LAS HERAS, J. (2008a). Natural post-fire dynamics and serotiny in 10-year-old *Pinus halepensis* Mill stands along a geographic gradient. *International Journal Wildland Fire*, 17(2):287-292.

MOYA, D., DE LAS HERAS, J., LOPEZ-SERRANO, F. R. and LEONE, V. (2008b). Optimal intensity and age of management in young Aleppo pine stands for post-fire resilience. *Forest Ecology and Management*, 255 (8-9): 3270-3280.

MOYA, D., SARACINO, A., SALVATORE, R., LOVREGLIO, R., DE LAS HERAS, J. and LEONE, V. (2008c). Anatomic basis and insulation of serotinous cones in *Pinus halepensis* Mill. *Trees-Structure and Function*, 22 (4): 511-519.

MOYA, D., DE LAS HERAS, J., LOPEZ-SERRANO, F. R., CONDES, S. and ALBERDI, I. (2009). Structural patterns and biodiversity in burned and managed Aleppo pine stands. *Plant Ecology*, 200 (2): 217-228.

SALVATORE, R., MOYA, D., PULIDO, L., LOVREGLIO, R., LOPEZ-SERRANO, F. R., DE LAS HERAS, J. and LEONE, V. (2010). Morphological and anatomical differences in Aleppo pine seeds from serotinous and non-serotinous cones. *New Forests*, 39(3): 329-341.

TRABAUD, L., MARTÍNEZ-SÁNCHEZ, J. J., FERRANDIS, P., GONZÁLEZ-OCHOA, A. I. and HERRANZ, J. M. (1997). Vegetation epigee et banque de semences du sol: leur contribution a la stabilite cyclique des pinedes mixtes de *Pinus halepensis* et *P. pinaster*. *Canadian Journal of Botany*, 75: 1012-1021.

Editor: María José Vicente (maria.vicente@upct.es)

Administration and support: Document Service

ISSN 2172-0436