161

JME

Journal of Mediterranean Ecology

The impact of wildfire season on regeneration of *Quercus Pyrenaica* forest and *Pinus Sp.* stands

L. Domínguez , L. Calvo , E. Luis.
Área de Ecología. Facultad de Biología. Universidad de León. 24071 León. Spain.
deglcg@unileon.es

Abstract

This paper discusses the effects of wildfire season on the regeneration of *Quercus pyrenaica* woodland and a *Pinus* sp. stand. This study analyses differences in the recovery of two plant communities after autumn and spring wildfires. For this purpose, two communities were studied: a *Quercus pyrenaica* community and a *Pinus* stand artificially planted in a shrubland community. The results indicate that the *Quercus* community had a greater recovery capacity than the *Pinus* stand. This is due to the fact that the *Quercus* community had a faster recovery rate and, in addition, reached higher cover values in the same period of time. The influence of fire season was shown by more rapid recovery after the spring fire than after the autumn burn. The woody species, mainly typical sprouting taxa such as *Quercus pyrenaica*, *Erica australis* and *Genistella tridentata*, dominated from the beginning after the spring fires, whilst perennial herbs such as *Luzula lactea*, *Asphodelus albus* and *Arenaria montana*, were dominant during the first months after the autumn fire. The changes in the values of the structural parameters confirmed the greater recovery capacity in the oak community and the zone burned in spring.

Introduction

At present, forest fires are the most important cause of damage to the natural environment in the Mediterranean basin (Vélez, 1990). Amongst the countries of the Mediterranean basin, Spain is one of those with a relatively high fire risk and severity of burning (Vélez, 2000). Within Spain, León is the province with the largest wooded surface area burned in the last few years. Forty per cent of this area is covered by coniferous species, mainly *Pinus sylvestris* and *Pinus nigra*, and the remaining 60% by *Quercus* species (Del Hierro; personal communication). Amongst the *Quercus* species, 85% of the area burned is occupied by communities of *Quercus pyrenaica* (Vélez, 2000).

The effects of fire on vegetation are usually the most obvious impact of burning. Fire affects natural ecosystems by consuming plants, altering successional patterns and changing vegetative resources such forage, wildlife habitats, etc. Understanding how fire affects vegetation is often a key to holistic, ecosystem-based, natural resource management (De Bano *et al.*, 1998).

Amongst the factors influencing post-fire regeneration, the most important are: the type of community existing prior to fire and the time of year when it occurs, as this determines the intensity and severity of the fire.

Several authors have examined the importance of the season of fire to the recovery processes. In studies related to fires in coniferous forests, Ohmann & Grigal (1981) have found that the greatest difference between spring and summer fires is in the degree of plant destruction. Spring fires destroy litter, but have a limited impact on the upper soil horizons, so they do not significantly alter soil humidity, chemical characteristics, etc. In the case of fires at the end of summer or at the beginning of autumn, the higher degree of damage caused to the ecosystem can be directly attributed to the increase in plant inflammability after the low rainfall period and the

high temperatures reached by the fire (Allen & Partridge, 1988). Trabaud (1980) also states that the main differences in recovery after a spring fire and a summer fire occur mainly in the first year. However in the literature there is a limited amount of information about the effect of fire season in regeneration of two communities, one natural and other artificial, that have planted in the same area, both of which have suffered from very frequent fires.

Another characteristic determining recovery capacity after fires is the type of community existing before them. The degree of maturity of the community subjected to fires will influence how and when recovery begins.

The main aim of this study was to analyse the differences in plant recovery after a spring fire and a summer fire in two examples of a *Quercus pyrenaica* community and a *Pinus sp.* stand, which represented different stages of maturity of the same climax.

Materials and methods

The study of post-fire regeneration was carried out in two zones burned by wildfires. The first study zone, the Autumn fire, was at a height of 1080 m, UTM coordinates: 30TTN772304. It suffered from a wildfire at the end of September 1995, in which two types of adjacent communities were burned, one dominated by a 30 year-old *Pinus nigra* stand and the other by a *Quercus pyrenaica* community.

The second study zone, the Spring fire, was at a height of 1020 m, UTM coordinates: 30TUN295272. It suffered a wildfire in March 1997, in which a 22 year-old *Pinus sylvestris* stand and a second *Quercus pyrenaica* community one were burned.

The *Pinus sp.* communities were artificial plantations in both study areas, referred to here by the term 'Pinus stand'. The *Quercus pyrenaica* communities were natural communities in both study areas and are more than 50 years-old. *Quercus pyrenaica* communities in this region have frequently been affected by human activities. Amongst the most important are forest fires. These long-term perturbations have led to the extensive destruction of tree-dominated vegetation, transforming it into shrubland. The *Pinus* stand was planted in these shrubland communities.

The soil of both study zones is humic Cambisol (Junta de Castilla y León, 1987). The climate is subhumid Mediterranean with a central European tendency to long, hard winters (Rivas Martínez *et al.*, 1987). They belong to *Quercus pyrenaica* (*Festuco heterophyllae-Querceto pyrenaicae* sigmetum) series (Penas *et al.*, 1995).

Two sampling areas were established in each study zone, one in the community dominated by *Pinus* sp. and the other in the oak community (*Quercus pyrenaica*). Sixty 50 x 50 cm randomly distributed sampling units were recorded in each sampling area. Measurements were made 1, 9, 14, 19 and 32 after the autumn fire and 1, 2, 3, 4, 5 and 12 months after the spring fire. The difference in the sampling time was due to the fact that the burned trees were extracted from the spring fire after 12 months and the community was greatly modified, so measurements ceased one year after the fire. In the spring fire, 60 sampling units were located in unburnt *Quercus pyrenaica* and *Pinus* communities; these are considered to be control samples. All the herbaceous and woody species present in each sampling unit were recorded in terms of cover percentage in vertical projection (Calvo Sendin *et al.*, 1994). This sampling method has been used in many investigations of regeneration after fire (Calvo *et al.*, 1998; Tárrega *et al.*, 2000)

The data obtained were used to calculate the percentage cover of the different life forms (annual herbs, perennial herbs and woody species). The structural parameters of the community, namely species richness and abundance, were measured, and the Shannon index (Shannon & Weaver, 1949) and uniformity (Pielou, 1969) were calculated.

An analysis of variance of repeated measures was carried out to compare the results obtained in the two zones, Autumn and Spring, as well as in the two communities (*Quercus* community and *Pinus* stand). To normalise errors percentage cover was arc sin transformed (Sokal & Rohlf 1979). The Fisher test was applied as a contrast stadigraph. The David *et al.* (1954) test was used to check the normality and the Cochran (1941) test to check the homoscedasticity.

Plant nomenclature follows Tutin *et al.* 1964-1980.

Results

These is a general tendency for global cover values (woody and herbaceous species) to increase significantly through time, both in the *Quercus* community and in the *Pinus* stand (Fig. 1). In both zones, burned in autumn and in spring, this increase was more marked in the *Quercus* community than in the *Pinus* stand. This suggests that there are differences between the communities. On considering the fire season and comparing the situation in the first year of regeneration, higher cover values were observed in the zones burned in spring than in those burned in autumn.
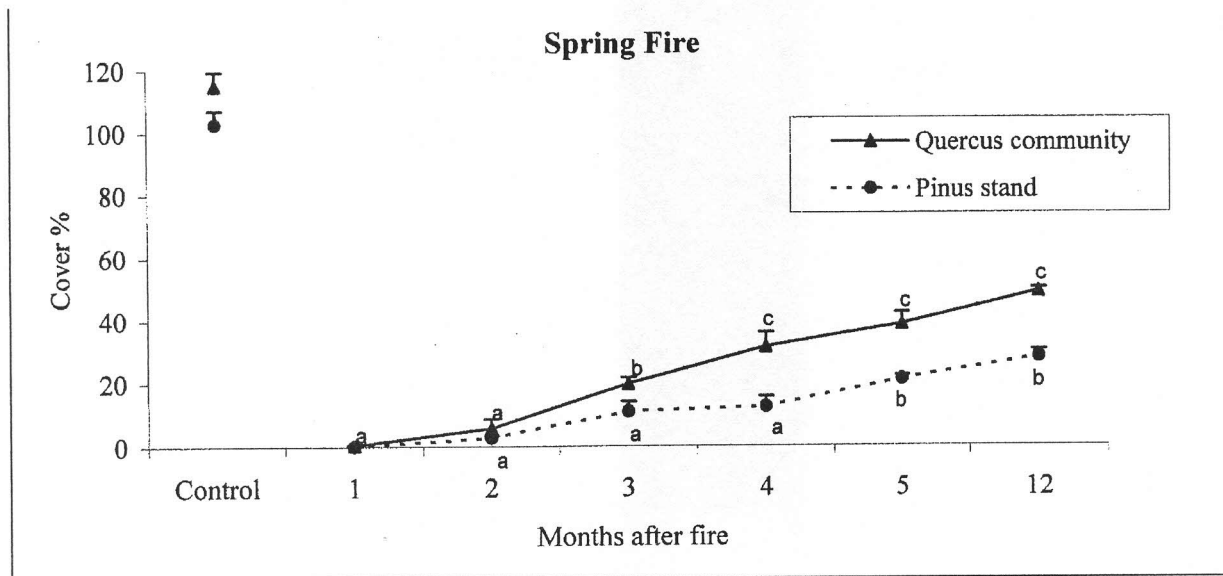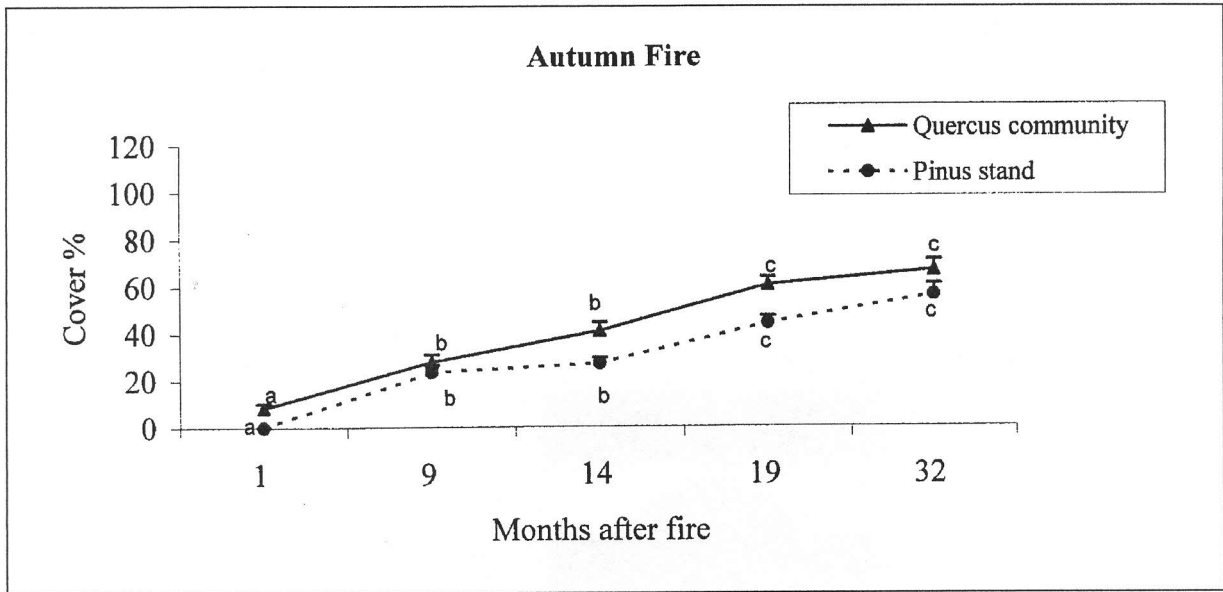
Fig.1. Mean cover of the total vegetation in the *Quercus* community and *Pinus* stand in the two burned zones.

Variations in the cover values of the life forms showed differences between communities and between fire season (Fig. 2). The main differences between the communities were observed in the recovery rate during the first stages after the fire. The *Quercus* community shows the highest cover values in the three life forms examined during the first year after the fire. This community also showed relatively rapid plant recovery during the first month af-

ter the fire, mainly due to perennial herbs. This response in the first month was more marked in the zone burned in autumn than in that burned in spring.

In the autumn fire, the woody species with high cover values in the oak wood community were *Erica australis*, *Genistella tridentata*, *Quercus pyrenaica* and *Halimium alyssoides*, and in the *Pinus* stand, always with lower values, *Halimium alyssoides*, *Genistella tridentata*, *Erica australis*, and *Pinus sylve-*
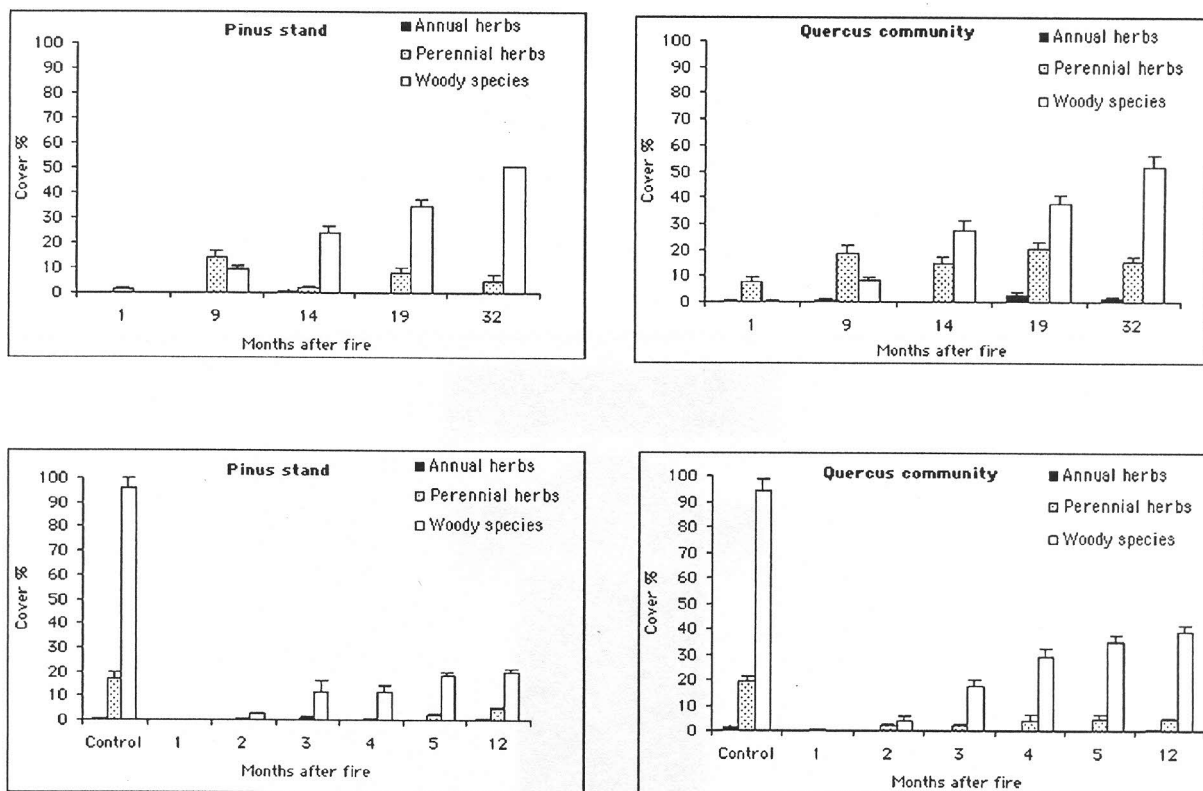
Fig.2. Mean cover of the life forms (annual, perennial herbs and woody species) in the Quercus community and Pinus stand in the two burned zones. 0= Original situation; 1,2,3,... 32= Months after fire.

stris. In both communities percentage cover for woody species increased through time. Species composition in both communities was very similar, except for the dominant woody species. This explains the absence of significant differences between the *Quercus* community and the *Pinus* stand.

After the spring fire, woody species were clearly dominant in the *Quercus* community and in the *Pinus* stand from the first few months after the fire. The woody species *Arctostaphylos* uva-ursi, *Quercus pyrenaica*, *Erica australis* and *Halimium alyssoides* dominated the *Quercus* community. In the *Pinus* stand, *Halimium umbellatum*, *Halimium alyssoides* and *Erica australis* were dominant. The presence of *Quercus pyrenaica* sprouts were also important in the zone previously occupied by the *Pinus* stand. There were significant differences between the two communities in this zone, as the recovery rate in the oak community was much more rapid than in the *Pinus* stand.

Among perennial herbs, after the autumn fire, the most representative species in the oak wood were: *Luzula lactea, Arenaria montana, Asphodelus albus* and *Festuca rubra*, with *Asphodelus* albus and *Arenaria montana* most abundant in the *Pinus* stand. The

changes in herbaceous cover through time did not show significant differences between oak and *Pinus* communities (Fig. 2), except between the first and last sampling visits. However, cover values were always higher in the *Quercus* community than in the *Pinus* stand, resulting in significant differences between the two communities throughout the study period.

After the spring fire, the number of species was slightly higher in the *Quercus* community, where *Arenaria montana, Luzula lactea, Festuca rubra, Narcissus triandrus* and *Lotus corniculatus* were dominant. This higher number of perennial herbs corresponded to higher cover percentages, with appreciable differences between communities throughout the study period.

In the zone burned in autumn, annual herbs attained higher cover values than in the zone burned in spring. In the oak community burned in autumn *Aira caryophyllea* and *Andryala integrifolia* attained relatively high values. In the zone burned in spring, colonisation started one year after the fire. The presence of *Aira caryophyllea* in the oak wood one month after the fire was ephemeral and values are very low (0.02%).

As regards the percentage of bare soil, values decreased as vegetation cover increased. This can be
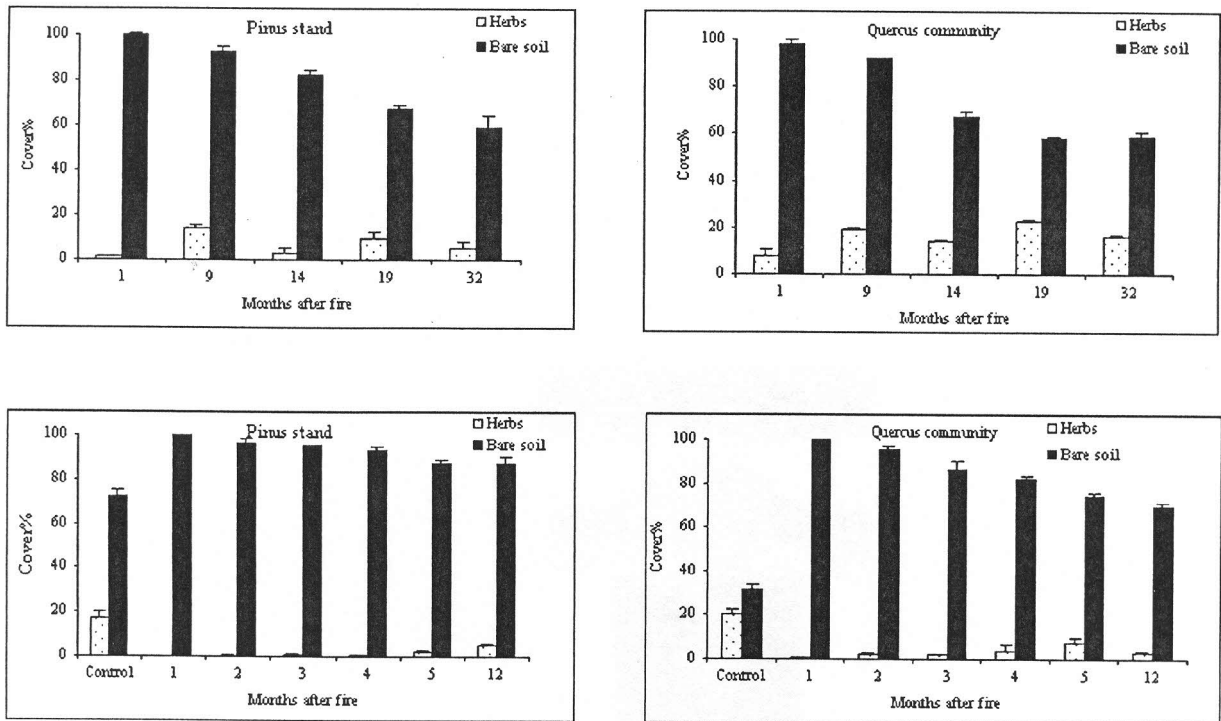
Fig.3. Mean cover of herbaceous species and bare soil in the two plant communities and in the two burned zones.

clearly seen in the autumn fire, where the study was continued for longer. In general and in both zones, these percentages were higher in the *Pinus* stands than in the oak communities (Fig 3). Comparing the fire season, one year after the fire the amount of bare soil were higher in the zones burned in autumn than in those burned in spring.

The structural parameters show a clear difference between the zones burned in autumn and in spring, as well as between communities (Fig. 4). After the autumn fire, richness, evenness and H' were higher in the *Quercus* community than in the *Pinus* stand. However, in the spring zone this situation only occurred during the first and second month after wildfire. After this period, the situation was reversed. The dominance of woody species in the *Quercus* community had a negative influence on the values of the structural parameters of this community. After the spring fire there was a clearer rise both in richness and diversity throughout the year, whilst the greatest increase appeared from month 19 in the autumn zone.

Discussion

In post-fire succession studies many factors have to be taken into account, such as the characteristics of the vegetation before the fire, the season when it occurs, the intensity of the fire, the concentration of ash, nutrients added to the soil, rain, air and soil temperature, and animal populations associated with the wood. All these parameters as a whole determine the response of the vegetation. In wildfires, however, it is very difficult to analyse many of these parameters: only the season is easily recorded.

The importance of the time of year of the fire lies in the degree of plant destruction. Spring fires, due to the higher levels of moisture in the fuel and in the atmosphere, reach lower intensities than autumn fires, which have a limited impact on resprouting or germination (Ohmann & Grigal, 1981). In the case of fires at the end of summer or beginning of autumn, fuels are drier and therefore burn more easily, resulting in very high intensities which, in some cases, have a negative effect on resprouting in comparison with germination (Allen & Partridge, 1988; Canadell *et al.*, 1991; Moreno & Oechel, 1994; Cavero & Ederra, 1999). In the autumn zone, the predominance of perennial herbs during the first stages can probably be explained by the negative.effect of fire on typical resprouters (most of the woody species in the zone). However in these areas, perennial herbaceous plants, namely hemicryptophytes and geophytes, have vegetative and reproductive post-fire regeneration mechanisms. They commence resprouting after the first winter rains from protected underground stem bases, bul-

bs, tubers, and corms, as well as from fire-stimulated seed growth. Similar effects are reported by Clark (1988) for summer fires, which affect the organs used by the woody species to resprout and thus make recovery slower.

In contrast, after the spring fire recovery starts two months after the fire in the *Pinus* stand and in the oak community, consisting of resprouting woody species (*Erica australis, Genistella tridentata*) and seeders e.g. *Halimium alyssoides*, which dominate during the whole study period. The deficit in cover of both annual and perennial herbs is possibly due to the fact that they have not had enough time to initiate the reproductive period before the fire occurred, as the period of vegetative activity in these zones starts at the end of March or beginning of April. These results correlate with those reported by McPherson (1995), according to whom spring fires can damage annual grasses that emerge following winter rains but which have not had time to produce seeds.

The *Pinus* community recovered very slowly. Both types of *Pinus*, *Pinus sylvestris* and *Pinus nigra*, do not resprout at all. They are therefore obligatory seed regenerators for which fire provides the opportunity for their natural regeneration under a dense shrubland understory (Naveh 1999). The fact that the *Pinus* stand represents a community not characteristic of the zone is shown by the results of sampling in the control *Pinus* stand, where the total plant cover percentages observed (except the adult pine cover) were considerably lower than those of the control oak community. In general, recovery in the *Pinus* communities during the first few years of study was always slower than that of the climax community. Together with this slower development of vegetation cover, the community structure was also lower than that observed in the oak community.

A dominance of perennial, herbaceous or woody species and only a small proportion of annuals (according to the season the fire occurs) were observed in the oak communities a short time after the fire. These results agree with those reported by other authors (Tárrega & Luis, 1989) and confirm the idea that perennial species survived the fire either as seeds buried in the soil or through the survival of their subterranean organs (Trabaud, 1991, Calvo *et al.*, 1998, Naveh, 1999). It is difficult for perennial species of alien origin to become established as they have slower dispersal mechanisms that those of annuals (Tárrega & Luis, 1990).
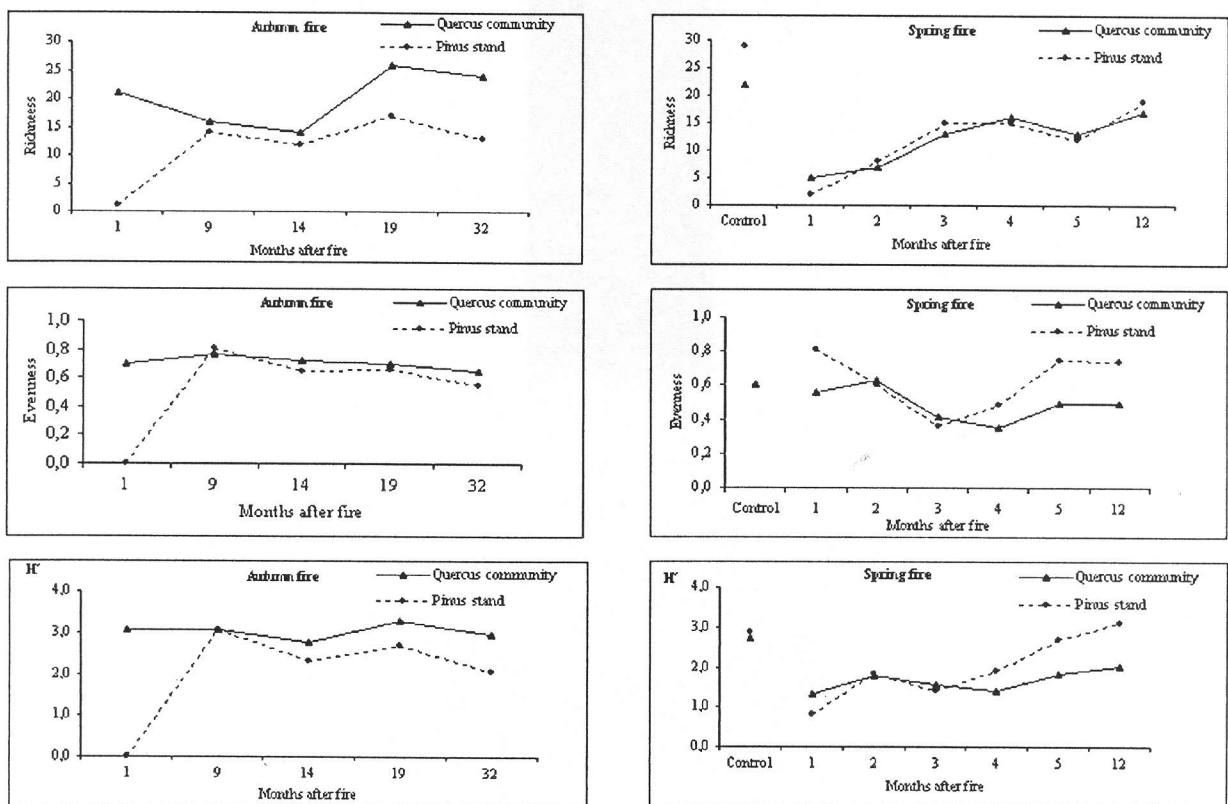

Fig.4. Structural parameters (richness, evenness and H') of the two communities in the two burned zones.

The low cover values of annual herbs do not correlate with those found in other Mediterranean communities one year after a fire (Kruger, 1979; Arianoutsou & Margaris, 1981; Cañas *et al.*, 1990; Casal *et al.*, 1990; Keeley, 1981; Kazanis & Arianoutsou, 1996). One possible explanation is the quantity of precipitation that the study zones received after the fire. However, both areas were very wet the year after fire (985 mm) and for this reason, this factor cannot explain the limited presence of these species. These communities probably have a high disturbance rate, which makes if difficult to maintain a large quantity of annual seeds in the soil seedbank and there may also be a lack of typical fire followers. This same fact is presumably the reason for the dominance of woody species in both study zones, from the second month after the spring fire and from the ninth month after the autumn fire (Calvo *et al.*, 1998). The vegetation of these ecosystems has mechanisms which allows it to survive or regenerate rapidly after the fire and this is easily observable in the woody species with the presence of lignotubers, for example in *Erica australis*, or root sprouts, as in *Quercus pyrenaica*. *Cistaceae* like *Halimium alyssoides* also benefit as their seeds germinate after being subjected to thermal shock (Thanos *et al.*, 1992, Herranz *et al.*, 1999). Thus, after the fires no true secondary succession is produced in the classical sense of the term (substitution of one species by others), but rather autosuccession consisting of the same species, mainly woody taxa, which were present in the original situation. These results agree with those of other authors who have studied post-fire regeneration in Mediterranean systems (Trabaud, 1985, 1990; Trabaud & Lepart, 1980, 1981; Prodon *et al.*, 1984; Kutiel & Kutiel, 1989; De Lillis & Testi, 1990; Casal *et al.*, 1990; Cañas *et al.*, 1990; Clemente *et al.*, 1996).

Therefore, it can be concluded that the oak community has a more rapid recovery capacity than the *Pinus* stand. This is determined by the speed with which recovery starts and by the percentage cover attained during the study period. The influence of fire season is shown by smaller alterations to the community burned in spring, resulting in more rapid recovery than the zone burned in autumn. Woody species dominate from the first instance in the zones subjected to spring fires, whilst perennial herbs are predominant during the first few months after the autumn fire. After nine months, both zones are dominated by woody species present in the original situation.

References

Allen, R.B. & Partridge, T.R. 1988. Effects of spring and autumn fires on the composition of *Chionochloa rigida* Tussock Grassland, New Zealand. Vegetatio, 76; 37-44.

Arianoutsou, M. & Margaris, N.S. 1981. Early stages of regeneration after fire in a phrygranic ecosystem (East Mediterranean). I Regeneration by seed germination. Biologie Ecologie Méditerranéenne, 8: 119-128.

Calvo L., Tárrega R. & Luis E., 1998 Twelve years of vegetation changes after fire in an Erica australis community. Pp123-136. In: Trabaud L. (Ed), Fire Management and landscape Ecology. International Association of Wildland Fire. Fairfield, Washington.

Calvo Sendin, J.F. Ródenas Lario, M., Palazón Ferrando, J.A. & Ramírez-Díaz, L. 1994. Ecología General. Prácticas y Experiencias (I). Universidad de Murcia. Murcia.

Canadell, J.; Lloret, F. & López-Soria, L. 1991. Resprouting vigour of two Mediterranean shrub species after experimental fire treatments. Vegetatio, 95: 119-126.

Cañas, J.; Llimona, F.; Arrizabalaga, A. & Matheu, E. 1990. Rehabilitación tras el fuego: el caso de los incendios forestales en Monserrat. Quercus: 12-17.

Casal, M.; Basanta, M.; González, F.; Montero, R.; Pereiras, J. & Puentes, A. 1990. Pp 33-42. In J.G. Goldammer & M.J. Jenkins (eds), Post-fire dynamics in experimental plots of shrubland ecosystems in Galicia (NW Spain). Fire in Ecosystem Dynamics. The Hague.

Cavero, R.Y. & Ederra, A. 1999. Evolución de la composición florística post-fuego en un carrascal de Navarra. Pirineos, 153-154: 61-100.

Clark, S.S. 1988. Effects of hazard-reduction burning on population of understorey plant species on Hawkesbury sandstone. Australian Journal of Ecology, 13: 473-484.

Clemente, A.S.; Rego, F.C. & Correia, O.A. 1996. Demographic patterns and productivity of post-fire regeneration in Portuguese Mediterranean Maquis. Int. Journal Wildland Fire, 6 (1): 5-12.

Cochran, W.C. 1941. The distribution of the largest of a set of estimated variances as a fraction of their total. Ann. Eugen. (Land), 11: 47-61.

David, H.A.; Hartley, M.O. & Pearson, E.S. 1954. The distribution of the ratio in a single normal sample of range to standard deviation. Biometrika, 41: 482.493.

De Lillis, M. & Testi, A. 1990. Post-fire dynamics in a disturbed Mediterranean community in central Italy. Pp 53-62. In J.G. Goldammer & M.J. Jenkins (eds). Fire in Ecosystem Dynamics. The Hague.

DeBano, L.F., Neary, D.G. & Ffolliott, P.F. 1998. Fire´s effects on ecosystems. John Wiley & Sons, Inc. New York.

Herranz, J.M.; Ferrandis, P., & Martínez-Sánchez, J.J. 1999. Influence of heat on seed germination of nine woody *Cistaceae* species. Inter. J. of Wildland Fire 9(3): 173-182.

Junta de Castilla y León, 1987. Mapa de suelos de Castilla y León. Junta de Castilla y León. España.

Kazanis, D. & Arianoutsou, M. 1996. Vegetation composition in a post-fire successional gradient of *Pinus halepensis* forest in Attica, Greece. Int. J. Wildland Fire 6 (2): 83-91.

Keeley, J.E. 1981. Fire regimes and reproductive cycles. Pp: 231-277. In: Mooney, H.A.; Bonnicksen, T.M.; Christensen, N.L.; Lotan, J.E. & Reirners, W.A. (eds.). Fire Re-

gimes and Ecosystem Properties USDA For. Serv. Gen. Tech. Rep., W.O.

Kruger, F.J. 1979. South African heathlands. Pp: 19-80. In: Specht R.L. (ed) Heathlands and related shrublands of the world. A descriptive study. Amsterdam: Elsevier. Amsterdam.

Kutiel, P. & Kutiel, H. 1989. Effects of a wildfire on soil nutrients and vegetation in an Aleppo *Pinus* forest on Mount Carmel, Israel. Pirineos, 134: 59-74.

McPherson, G.R. 1995. The role of fire in the desert grasslands. Pp. 130-151. In: McClaran, M.P. & T.R. Van Devender, (eds.) The desert grassland. University of Arizona Press, Tucson. Arizona.

Moreno, J.M. & Oechel, W.C. 1994. Fire intensity as a determinant factor of post-fire plant recovery in Southern California Chaparral. Pp: 26-45. In: Moreno, J.M. & Oechel, W.C. (eds), The role of fire in Mediterranean-Type ecosystems. Springer-Verlag. New York.

Naveh, Z. 1999. The role of fire as an evolutionary and ecological factor on the landscapes and vegetation of Mt. Carmel. Journal of Mediterranean Ecology 1: 11-25.

Ohmann, L.F. & Grigal, D.F. 1981. Contrasting vegetation responses following two forest fires in Northeastern Minnesota. The American Midland Naturalist, 106 (1): 54-63.

Penas, A., García, M.E. & Herrero, L. 1995. Series de vegetación. Pp: 29-40. En: Atlas del Medio Natural de la provincia de León. Instituto Tecnológico Geominero de España y Diputación de León.

Pielou, E.C. 1969. The measurement of diversity in different types of biological collections. J. Theor. Biol., 13: 131-144.

Prodon, R.; Fons, R. & Peter, A.M. 1984. L'impact du feu sur la vegetation, les oiseaux et les micromammifères dans diverses formations méditerranéennes des Pyrénées orientales: premiers résultats. Revue d'Ecologie, Terre et Vie 39:129-158.

Rívas Martínez S., Gandullo J.M., Allué J.L., Montero J.L., & González J.L. 1987. Memoria del mapa de series de vegetación de España. ICONA. Madrid. Spain.

Shannon, C.E. & Weaver, W. 1949. The mathematical theory of communication. Univ. Illinois Press. Urbana.

Sokal, R.R. & Rohlf, F.J. 1979. Biometria. Principios y métodos estadísticos en la investigación biológica. Blume ediciones. Madrid.

Tárrega, R. & Luis, E. 1989. Sucesión post-fuego y mecanismos de supervivencia en comunidades de *Quercus pyrenaica* de la provincia de León. Options Méditerranéennes-Sérre Séminaires, 3: 137-140.

Tárrega, R. y Luis, E. 1990. Forest fires and climatic features in León province (Spain)-Fire effects on *Quercus pyrenaica* ecosystems. Pp: 63-69. In: J.G. Goldammer & M.J. Jenkins (eds), Fire in Ecosystem Dynamics. The Hague.

Thanos C.A., Georghiou K., Kadis C.C., & Pantazi C. 1992. Cistaceae: A plant family with hard seeds. Israel Journal of Botany 41 251-263.

Trabaud, L. 1980. Impact biologique et écologique des feux de végétation sur l'organisation, la structure et l'evolution de la végétation des garrigues du Bas-Languedoc. Thése Doct. Etat. Univ. Sci. Tech. Languedoc. Montpellier.

Trabaud, L. 1985. Aspect floristique de la recolonization des garrigues de *Quercus coccifera* et des forêts de *Pinus halepensis* après incendie in Bas Languedoc (Sud de France). Jornadas sobre bases ecológiques per la gestió ambiental: 13-16. Montesquiu (Ripollès).

Trabaud, L. 1991. Le feu est-il un facteur de changement pour les systèmes écologiques du bassin méditerranéen?. Sécheresse, no 3, (2): 163-174.

Trabaud, L. & Lepart, J. 1980. Diversity and stability in garrigue ecosystems after fire. Vegetatio 43: 49-57.

Trabaud, L. & Lepart, J. 1981. Changes in the floristic composition of a *Quercus coccifera* L. garrigue in relation to different fire regimes. Vegetatio 46: 105-116.

Tutin, T.G., Heywood, V.H., Burges, N.A., Valentine, D.H., Moore, D.M., Walters, S.M. & Webb, D.A. 1964-1980. Flora Europea, Cambridge University Press.

Vélez, R. 1990. Los incendios forestales en España. Ecología, Fuera de serie 1: 213-221.

Vélez, R. 2000. La defensa contra incendios forestales. Fundamentos y experiencias. McGraw Hill. Madrid.