Pinsapo forests: past, present and future

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The Iberian and Rifian pinsapo forests are now stable, thanks to the work of the various conservation organisations for protected natural areas and the abandon of the area by rural inhabitants, which has ended the livestock raising and logging to which these forests were subjected for many years. However, their continued survival is threatened by forest fires and climate change.

Sierra de Ronda (Málaga) pinsapo forest.
Photo L. García Esteban and P. de Palacios.

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RÉSUMÉ

FORÊTS DE PINSAPOS : PASSÉ, PRÉSENT ET FUTUR

Vu le caractère unique de la découverte, ce travail relate les trois expéditions botaniques dans les enclaves naturelles d'*Abies pinsapo* Boiss. La première fut entreprise en 1837 par le botaniste suisse Edmond Boissier, la deuxième en 1928 par les ingénieurs forestiers Luis Ceballos Fernández de Córdoba et Manuel Martín Bolaños, et la troisième en 1946 par un autre ingénieur forestier, Santiago Sánchez Cózar. Ces deux dernières expéditions ont été conduites dans le Rif marocain, respectivement aux monts Mago et Tazaout, et ont permis d'identifier les sapins rifiens comme étant une variété du sapin d'Andalousie. Actuellement, les forêts de pinsapos ibériques et du Rif sont stabilisées grâce au travail respectif des organismes de conservation des espaces naturels protégés et à l'exode de la population rurale. Cela a contribué à l'abandon de l'élevage et de l'exploitation forestière qui ont caractérisé ces sites pendant des années. En revanche, les incendies et les changements climatiques menacent désormais la survie de ces forêts.

Mots-clés : *Abies pinsapo, A. marocana, A. tazaotana, A. numidica*.

ABSTRACT

PINSAPO FORESTS: PAST, PRESENT AND FUTURE

In view of the unique nature of the discovery, this article provides an account of the three botanical expeditions made to the natural enclaves of *Abies pinsapo* Boiss., first by the Swiss botanist Edmond Boissier in 1837, then by the Spanish forestry engineers Luis Ceballos Fernández de Córdoba and Manuel Martín Bolaños in 1928, and later by another Spanish forestry engineer, Santiago Sánchez Cózar, in 1946. The two later expeditions were to the Moroccan Rif, to Mount Mago and Mount Tazaout respectively, and it was these expeditions that enabled the Rifian firs to be identified as varieties of the Andalusian pinsapo fir. The Iberian and Rifian pinsapo forests are now stable, thanks to the work of the various conservation organisations for protected natural areas and the abandon of the area by the rural inhabitants, which has ended the livestock raising and logging to which these forests were subjected for many years. However, forest fires and climate change represent a threat to their continued survival.

Keywords: *Abies pinsapo, A. marocana, A. tazaotana, A. numidica*.

RESUMEN

PINSAPARES: PASADO, PRESENTE Y FUTURO

Por la singularidad del descubrimiento, en este trabajo se relatan las tres expediciones botánicas que se realizaron a los enclaves naturales de *Abies pinsapo* Boiss.: en 1837 por el botánico Edmond Boissier, en 1928 por los Ingenieros de Montes Luis Ceballos Fernández de Córdoba y Manuel Martín Bolaños y, en 1946, por el también Ingeniero de Montes, Santiago Sánchez Cózar. Estas dos últimas expediciones se realizaron en el Rif marroquí, en los montes Magó y Tazaout respectivamente, y permitieron ubicar a los abetos rifeños como variedades del pinsapo andaluz. Actualmente los pinsapares ibéricos y rifeños se encuentran estabilizados gracias a las respectivas figuras de protección de espacios naturales protegidos y al éxodo por parte de la población rural, que ha conducido al abandono de las actividades ganaderas y madereras que durante años soportaron estos bosques. No obstante, los incendios y el cambio climático amenazan su permanencia.

Palabras clave: *Abies pinsapo, A. marocana, A. tazaotana, A. numidica*.

Introduction

Sierra de Grazalema (Cádiz) pinsapo forest.
Photo L. García Esteban and P. de Palacios.

Abies pinsapo Boissier is the westernmost fir in the entire Mediterranean Arc, and along with the other Mediterranean firs it is currently a good indicator of the potential influence of climate change on the region's vegetation.

Climate fluctuations in the Quaternary caused these firs to take refuge in shady areas at medium altitudes with very high average rainfall.

Terpene analyses of Mediterranean firs seem to indicate that they all came from a common ancestor in the Aegean area, quite similar to those found today, which would later have split into two large groups: the Pontic fir of Asia Minor, and the Balkan Peninsula fir. At the end of the Tertiary, these species would have been distinct and ready to evolve and migrate under the influence of the Quaternary climate fluctuations mentioned previously.

Terpene analyses of the eastern populations of *A. alba* (in Romania and the Rhodope Mountains) and *A. bornmuelleriana* have shown more similarity between these two species than between *A. alba* and *A. cephalonica*, which would indicate that the ancestral Pontic fir contributed to the individualisation of *A. alba* and its ability to colonise Central and Western Europe (García, 1993; Scaltsoyiannes *et al.*, 1999). This theory coincides with the Pliocene remains of *Abies alba* found in Western Europe (Gaussen, 1964; Liu, 1971).

On the basis of the *Abies* fossils found and the antiquity of the morphological features of this species, the entry of the genus into the Iberian Peninsula is determined as having occurred through the Pyrenees (Liu, 1971; Parducci, 2000), continuing through the Thetic bridges from the southeast of France → Majorca → Granada → Sierra de Ronda → Sierra de Grazalema → Sierra Bermeja, and as far as the Moroccan mountain regions of Tazaout and Talassemtane and the Babor Mountains in Algeria.

Nitzelis (1969) *in* Farjon (1990), considers *A. nebrodensis* to be a subspecies of *A. alba*, while Vicario *et al.* (1995), using genetic analyses based on allozyme, chloroplast DNA and RAPD markers, have concluded that the populations of *A. alba* and *A. nebrodensis* provide clear evidence for a classification into two taxonomically different groups.

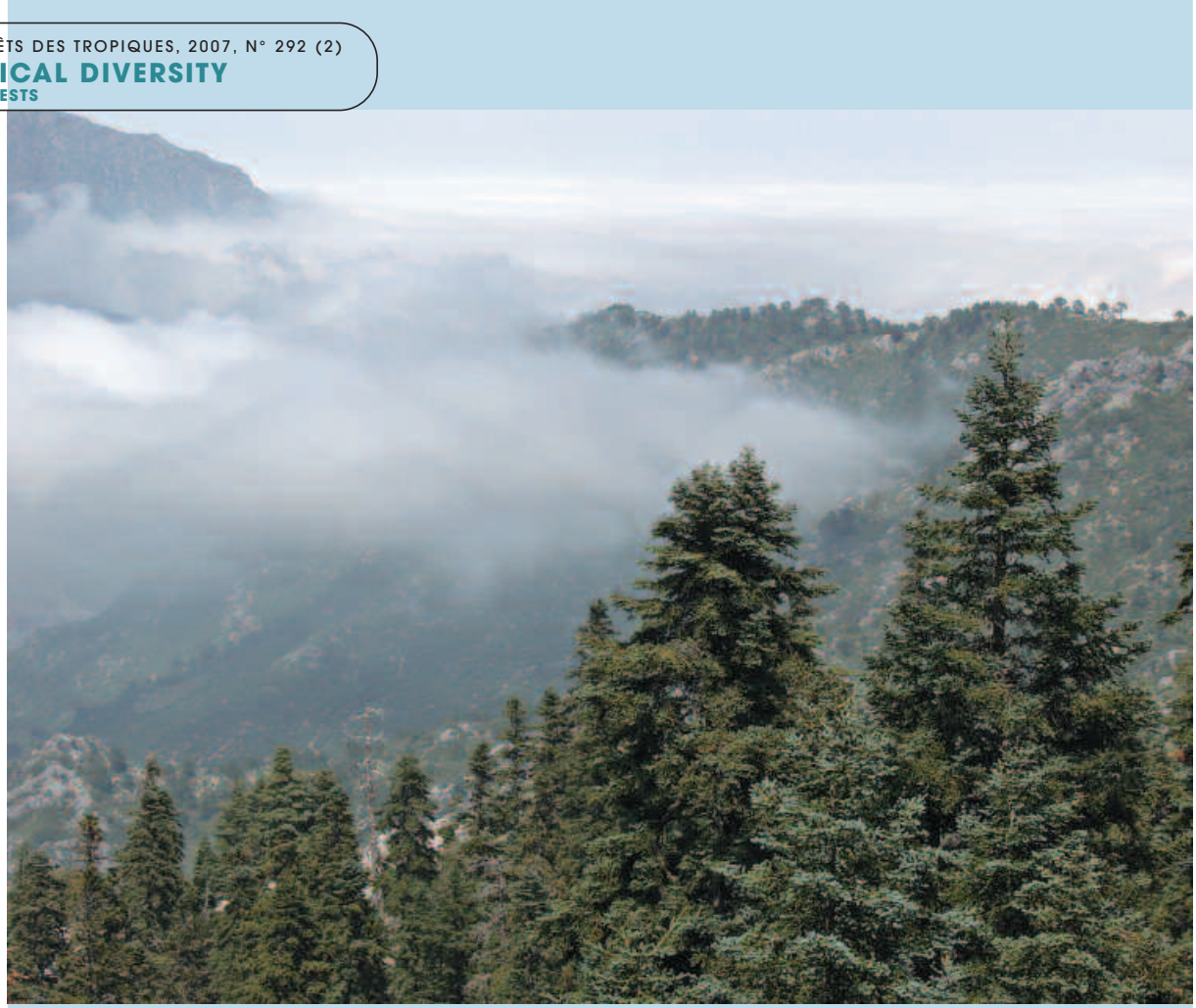
Some researchers maintain that the populations of *A. pinsapo, A. pinsapo* var. *marocana* and *A. numidica* may even have formed a single species before the final separation of the Iberian Peninsula from the north of Africa at the end of the Tertiary Age (Sánchez, 1946; Bocquet *et al.*, 1978; Jeanmonod, Bocquet, 1981; Blanca, 1993). This single species or relict fir, from which *A. silicica* probably derived as well (Flous, 1936), evolved into *A. pinsapo, A. pinsapo* var. *tazaotana, A. pinsapo* var. *marocana* and *A. numidica*. Of all of these, var. *tazaotana* shows the greatest vegetative vigour, and is perhaps the only one located in its ecological maximum. In view of this, it can be assumed that after *A. pinsapo* became established in Mount Tazaout in the north of Africa, it reached its climax due to the ecological conditions of the area. In other places, less demanding species such as *Cedrus atlantica* Man. have displaced the fir forests, by thinning the existing forests or even causing them to disappear from many areas where they must have existed.

One of the singular features of the Chefchaouen massif is that in some of its forests, such as Buhal-la, Desas and Lexchab, all exposed to the south, the firs show features similar to those of *A. pinsapo* var. *marocana*, while those in forests exposed to the north have more in common with *A. pinsapo* var. *tazaotana*.

The fragmentation of the *Abies pinsapo* range into isolated populations must have caused reproductive isolation between them due to the limited pollen dispersal of the pinsapo fir (Arista, Talavera, 1994). This could have triggered the speciation of these populations and their subsequent morphological differentiation (Arista, Talavera, 1995).

Although *A. pinsapo* var. *tazaotana* is geographically much closer to *A. pinsapo* var. *marocana*, it is, curiously, botanically closer to *A. numidica*. This circumstance shows that, within certain limits, geographical location did not influence the morphological speciation of the Moroccan firs (Sánchez, 1946).

The genetic divergence between the populations of *Abies pinsapo* and *var. marocana* and the possible existence of varieties of *A. pinsapo* have been demonstrated through a study on the inheritance of isoenzymatic variations in their seed tissue (Pascual *et al.*, 1993).



Talassemtane pinsapo forest.
Photo L. García Esteban and P. de Palacios.

Geographical distribution

Abies pinsapo Boiss. is located in the high mountain ranges of the western part of the Bética range in the south of the Iberian Peninsula, more specifically in Serranía de Ronda between the provinces of Málaga and Cádiz. It has little preference for soil type, although all the stands are located in shady areas of the range exposed to the north, east and northeast.

In the province of Málaga, it is located in two differentiated areas in the humid Mediterranean vegetation zone. The small area in Los Reales de Sierra Bermeja, which covered only 50 ha in 1933, had the privilege of being the first to be visited by Boissier. It extends over the municipalities of Genalguacil, Estepona and Casares, on peridotites, at altitudes ranging from 1200 to 1400 m. At present it covers about 40 ha and is in regression because of major forest fires in the area which have divided it into three groves.

Sierra de las Nieves is home to the most extensive area of pinsapo firs in the province, with over 3000 ha spread over the municipalities of Ronda, Tolox and Yunquera, at an altitude ranging from 1000 to 1800 m, in this case on limestone soils. There are also smaller stands and isolated groves in the Alcor, Caparaín, Real, Istán, Río Verde and Gialda ranges (Ceballos, Vicioso, 1933; Ceballos, Ruiz De La Torre, 1979). The pinsapo forest in Sierra de las Nieves has grown from 1000 ha in 1933 to 3000 ha today.

In the province of Cádiz, the pinsapo fir is found only in Sierra del Pinar, in the municipality of Grazalema, covering some 500 ha on Liassic and Jurassic limestone soils, at altitudes ranging from 1000 to 1650 m. This forest has grown from 200 ha in 1933 to 500 ha today. Groves and isolated stands are also found in the western part of Monte Prieto, the slopes of El Montón and on the northern slopes of Zafalgar and Los Pinos (Ceballos, Martín, 1930; Ceballos, Ruiz De La Torre, 1979).

The Moroccan pinsapo forests are located in the western Rif, in two enclaves less than 10 km apart. The northernmost enclave is located on Mount Tazaout or Yebel Tazaout in the Beni Sey-yel region, northeast of the settlement of Talambot. At present it covers 1500 ha, where *Abies pinsapo* var. *tazaotana* grows. The southernmost enclave is spread over the Chefchaouen mountains, from where the pinsapo forests surround the city of the same name, reaching as far as Ametrax to the southeast, with an area of 2600 ha. This is where *Abies pinsapo* var. *marocana* is found.

The first expedition in 1837

In April 1837 two pharmacists from Málaga, Félix Haenseler and Pablo Prolongo, showed the Swiss botanist Edmond Boissier a conifer branch which caught his attention because of its extremely short, thick leaves which were almost setiform. As the twig had no fruit, Boissier was unable to identify the species on this first encounter, although its features placed it in the fir group. When Haenseler told him that the fir forest was located in Sierra Bermeja, Boissier visited the area two weeks later accompanied by the two pharmacists, but the trees had no cones at that time and he therefore had to leave their description until the cones matured.

In the meantime, Boissier travelled to Sierra Nevada, where he compiled a herbarium of a large number of plants. On his return to Málaga at the end of September, he was able to describe the species in its entirety, this time in Sierra de las Nieves, in the Yunquera pinsapo forest. Boissier describes this exciting moment in his book "Voyage Botanique dans le Midi de l'Espagne" ... *tout près de là, le guide nous montra de loin le premier pinsapo; poussant des cris de joie nous courons pleins d'émotion, mais hélas, l'arbre ne portait point de fruits, un second, un troisième me donnent successivement de fausses espérances; en fin je suis assez heureux pour en apercevoir un dont les branches supérieures sont chargées de fruits. On se hâte de grimper pour les cueillir et il ne nous reste plus de doute sur le genre de cet arbre singulier. C'était certainement un Abies voisin de notre sapin blanc.* (Barbey, 1931).

The common fir he referred to was *Abies alba* or Pyrenean fir. Boissier published this discovery in 1838, ("Notice sur l'Abies pinsapo"), giving it the scientific name of *Abies pinsapo*. In this publication he described the morphological features of the pinsapo fir and the ecological conditions of the area in which it was located.

The second expedition: Ceballos and Martín Bolaños, 1928

In 1906 Dr Trabut, a lecturer at the University of Algeria, was responsible for calling attention to *Abies marocana* as a result of the studies he made on a fir twig collected in the Chefchaouen mountains in Morocco, which he considered different enough to justify the establishment of a new species. In 1916, he published the description of this fir once again, explaining how it differed from the other Mediterranean species. As he himself acknowledged in this second publication, he had not been able to enlarge on the first description with new details because in the intervening ten years he had been unable to collect either cones or catkins of the fir he had studied. The features of the leaves and shoots of the twig he had used in order to establish a new species, in particular the histological features of the leaves, served in the second publication to clearly individualise the species as an intermediary between *Abies numidica* de Lannoy and *Abies pinsapo* Boiss.

The fact that the two publications were based on a single twig lacking fruit and reproductive organs led some researchers to admit the new species with reservations.

On 26 May 1928, the Spanish forestry engineers Luis Ceballos and Manuel Martín Bolaños made an ascent of Mount Mago (2 130 m) in Chefchaouen, accompanied by an escort of four men and a woodcutter, in order to make a collection of Moroccan fir samples. The trees were known locally by the name of "esnaubaras", a term which designated pines and firs alike. The specimens were collected over an area of some 200 ha on the southwest slope, which was the least favourable for this species according to the authors. Although they had already observed the existence of another large stand of firs on the northwest slope, they suspected that the best specimens would be found on the north and northeast slopes. Unable to cover this territory because of the difficulty of the terrain, they requested a flight over the area from the High Commission in Tetouan on their return. Although the weather conditions were not favourable, they managed to ascertain from the air that the largest fir forests were in fact located on the northeast slope.

The observations the two forestry engineers had made on the ground, during the single day that the ascent of the southwest slope had taken, allowed them to note the presence of cedars (*Cedrus atlantica* Man.) mixed with and dominated by the fir forest. They considered this to be the westernmost site of the Targuist and Ketama cedar forests.

In relation to the state of conservation of the Chefchaouen fir forests, it would appear from the descriptions made by Ceballos and Martín Bolaños that the state of these forests in 1928 was better than that of the Spanish pinsapo forests, most likely because of the region's remoteness, as the authors had noted. They observed some specimens which had been burnt and some aged trees with deep holes dug out at the base, not for obtaining resin as in the case of the Castilian resin collectors, but for obtaining wood to make the troughs or basins used by local women for washing and which were sold on the Chefchaouen market.

After Ceballos and Martín Bolaños had made their botanical observations on the leaf morphology and histology, the male and female catkins and the scales and cones of the most recent dissemination, they concluded, as Dr Trabut had, that the Chefchaouen fir was in fact in an intermediate position between *Abies numidica* de Lannoy and *Abies pinsapo* Boiss., although closer to the latter. In their discussion they noted that although the differences observed could justify the creation of a new species, the large

Tazaout pinsapo forest.
Photo L. García Esteban and P. de Palacios.

number of affinities and similarities between the two firs, and the slight differences between them, meant that the Chefchaouen fir was a variety of the Spanish pinsapo fir. As a result of this discussion, the authors established the Moroccan fir as *Abies pinsapo* var. *marocana*.

Ceballos and Martín Bolaños made a collection of samples from twigs located both in the crown and at the base, in this way avoiding the pronounced foliar polymorphism they had observed. While these firs have tetragonal, needle-shaped leaves, the leaves in the lower branches and in the branches of young specimens are almost flat and pointed, and there are also intermediate stages. In fact, Ceballos and Martín Bolaños attributed the considerable foliar difference described by Dr Trabut to the fact that the branch he had been given had come from one of these intermediate foliar stages.

The third expedition: Sánchez Cózar, 1946

In 1946 the Spanish forestry engineer Santiago Sánchez Cózar made the final discovery of a stand of pinsapo firs on Moroccan soil while working for what was then the Spanish Protectorate Zone of Morocco.

Mount Tazaout or Yebel Tazaout, in the Beni Sey-yel region northeast of the settlement of Talambot, covers an area of 1200 ha, and the presence of firs in this area went unnoticed both by the scientific expedition of Dr Font Quer in 1930 and by the Spanish Forest Service. Having seen the trees from a distance, both parties had considered them to be cedars due to their similar appearance to pinsapo firs. In addition, the Forest Service had catalogued the area as a cedar forest. However, a fortuitous event led to a reconnaissance of the forest at the beginning of the summer of 1944, after a regional guard from the Uad-Lau area, who was patrolling the Beni Sey-yel region, reported illegal felling of “cedars”.

As the damage had to be evaluated, Sánchez Cózar was accompanied by Captain Barranco, the Commandant of Talambot, who stated that no Europeans or organised scientific expedition had ever been up to the area.

The ascent was made on the southwest slope. Very near the top they observed the first fir, which, due to the fact that it was growing in full sun, had a stunted form, no doubt similar to the Serranía de Ronda pinsapo firs, which avoid shady exposures. After passing the watershed at 1662 m, they discovered an extremely dense forest with a large number of specimens over 1 m in diameter and 34 to 40 m in height, very different from the degraded *A. pinsapo* var. *marocana* forests of Mago and Tisuka.

As they were not carrying tents, the two men could not stay overnight on the mountain and did not manage

Yesterday and today

to collect samples for the description of the fir. The next visit was planned for the autumn of the same year, in order to ensure there would be cones. However, a fierce storm prevented them from collecting specimens on this occasion as well, and they had to wait until the summer of 1946 in order to do so and make the final description.

That summer, in order to map the forest and estimate its resources, a cabin was built from trunks of pinsapo fir. Today, the flat area of mount Tazaout where it was built is known as Spanish Square, and there is still evidence of the cuts made at a height of approximately one metre.

According to Sánchez Cózar, there were two reasons for using the firs to build the cabin. First of all, it would have been expensive to transport any other material to the area because of the distances involved; and secondly, it allowed the quality of pinsapo fir wood as a construction timber to be tested.

The inventory was made on plots chosen at random, and it was discovered that there were no trees with a diameter from 10 to 40 cm. This was because the local people used a bucksaw whose maximum width only allowed them to make deep cuts on trees of this size.

The Tazaout fir is found at an altitude ranging from 1 280 to 1 790 m. In botanical terms, *A. pinsapo* var. *tazaotana* is much closer to *A. numidica* than to *A. pinsapo* var. *marocana*. The fact that the differences between *A. numidica* and *A. pinsapo* var. *marocana* are slighter than between *A. pinsapo* var. *marocana* and *A. pinsapo* var. *tazaotana* enabled Sánchez Cózar to propose *Abies tazaotana* as a new variety of *A. pinsapo* in 1946.

Since the time of the discovery of the pinsapo forests, their existence has been linked to the presence of humans. It is not a timber commonly used in construction, and when it has been used for this purpose this has only been at a local level, as its mechanical properties are poor. The most representative wooden structure using pinsapo fir as a construction timber is perhaps the seating in the Ronda bull ring (Peraza, 1964; Prioton, 1964). There is a legend that the masts of the Spanish Armada were built out of pinsapo fir, although this has not been confirmed. There is however written evidence of this timber being used in the building of the ships that would take Philip II to England in 1554, as 98 dozen boards of pinsapo fir were purchased for dividing interior compartments. In the 1930s, on the Berranga and Las Tablas estates in Sierra de Las Nieves, pinsapo firs were cut for use as railway sleepers for the Algeciras-Bobadilla line. Pinsapo fir wood was also used in mines and in the preparation of ice pits. A large part of the timber resources built up over time in some forests have been used for making paper pulp (Ceballos, Ruiz De La Torre, 1979). Although its firewood and coal are of mediocre quality, pinsapo fir wood was used for these purposes for some time by the local inhabitants, resulting in over-consumption which considerably reduced the forest area (Barbey, 1931). Even before the species was discovered scientifically, its branches were used in religious ceremonies in the region.

At the end of the nineteenth century, the forest guards in the Montes de Propios (municipal forests) of Ronda were given responsibility for one of the first initiatives to protect the pinsapo forests. Their main responsibility was to control the leasing of pasture, snow and esparto grass. In 1945 the three ravines where the Ronda pinsapo forests are located were acquired by the Spanish state.

The Grazalema pinsapo forest was later also purchased by the Spanish state through ICONA, the National Institute for Nature Conservation, and declared a Natural Park in 1984. Sierra de Las Nieves was similarly declared a Natural Park in 1989, and the area of Los Reales de Sierra Bermeja now has special protection as a Paraje Natural (Natural Site).

Nowadays the pinsapo forests in Morocco are protected and no logging is carried out. Perhaps the greatest human threat, after fire, is the growing of Indian hemp or hashish, which is gaining ground at medium altitudes corresponding to humid and sub-humid sites.

The firs of the circum-Mediterranean belt are perhaps, with minor exceptions, the plant formations least affected by man. This is due to several circumstances: firstly, the difficult access to the forests, which are located in rugged areas; secondly, the land the trees occupy is not suitable for agriculture; and finally, their timber is no match in terms of quality for pine or cedar.

The fir forests were only exploited in the first half of the twentieth century, coinciding with the period of the Spanish Protectorate Zone in Morocco, although always in accordance with controlled logging plans.

Final considerations

The climate of the Straits of Gibraltar and the altitude on both sides make this area a favourable enclave for the development of these conifers. The mist and high rainfall, as well as the presence of mountains over 2000 m high in some cases, give rise to unique bioclimatic conditions.

These species specialised from the time of their arrival in this area, and evolution linked to the ecological conditions allowed them to speciate while maintaining very pronounced morphological differences.

Of all the fir forests, the Tazaout forest has the greatest vegetative vigour. The trees are very large, up to 50 m in height with base diameters of 1.30 m. The vitality of the forest can be seen in the intense regeneration of the woodland, and although the firs are mixed with maples, cedars and even *Pinus pinaster* and *Pinus nigra*, they remain dominant.

However, since the fire in Tazaout in 2002 over a 200 ha area on the northern slope, there has been virtually no regeneration. The steep slope and competition with other less demanding species will most likely mean that regeneration will be slow in this area.

Although the Iberian pinsapo firs are smaller than the Rifian firs, the Sierra Bermeja firs have a form which resembles the latter more closely than the Grazalema and Ronda firs. The Sierra Bermeja forest is in fact the least vigorous, with smaller, twisted trees. In recent years, forest fires have fragmented and damaged this enclave.

Sierra de las Nieves is an area of many contrasts. In La Nava de San Luis, the firs are mixed with holm oaks at lower altitudes, although this association decreases with higher altitudes. The trees are larger and more vigorous than the firs in Sierra Bermeja, where fires have considerably diminished the area of the pinsapo forest. In fact, in the summer of 2004, fire destroyed an old south-east-facing stand on the way to the ice pits, in an area which includes *Quercus alpestris*, also described by Boissier. It is unlikely that the area will recover, as the exposure and poor soil are unfavourable.

The case of the pinsapo forest in Yunquera is quite different. This is a vigorous forest with a high level of regeneration, although it requires sylvicultural treatment in order to prosper. Without sylvicultural treatment there would be a great deal of competition in the forest because of its density, resulting in a forest with little resemblance to a climactic pinsapo forest.

The Grazalema pinsapo forest is quite distinct from the usual fir forests. It was endangered by excessive felling carried out by the owners in the first half of the twentieth century, as well as excessive livestock raising. However, regeneration progressed, and the firs were even able to colonise rocky ground. Nowadays, the trees in the forest are homogeneous in form, with high, almost even-aged diameter classes and little regeneration.

The final consideration is that the Moroccan forests are in better health than the Iberian forests, not because of conservation but because they respond to the better bioclimatic and biogeographical conditions. In fact, the Moroccan pinsapo forests have a greater altitudinal gradient and therefore, in the event of a climate crisis, they would respond with greater endurance.

The poorer conditions of the Spanish pinsapo forests give rise not only to less favourable morphological features but also to lower resistance to pests. The prolonged drought from 1992 to 1995 caused a loss of specimens growing in the least favourable conditions, and if the drought of the summer of 2005 is repeated in coming years, with a similar cycle, the loss of trees in borderline conditions will undoubtedly be repeated.

At present, the pinsapo forests are, in general, stabilised and recovering after years of fires, intensive pasturing by goats and use of the wood for firewood and charcoal. There is however, another (perhaps more insidious) risk slowly and inexorably closing in on them: climate change. Although Aussenac (2002) attributes *A. pinsapo* and *A. numidica* with having the greatest resistance to possible climate change, most likely because they have adapted for years to less favourable conditions than the other Mediterranean firs, it is clear that if droughts such as those seen recently continue, the altitude range will gradually decrease, the risk of pests will increase, and within a short time, in geological terms, the pinsapo firs will be faced with the challenge of their very survival.

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ARISTA M., TALAVERA S., 1994. Pollen viability and pollen dispersal capacity of *Abies pinsapo* Boiss. Silvae Genetica, 43: 155-158.

ARISTA M., TALAVERA S., 1995. Producción de piñas y ciclos de cosechas en *Abies pinsapo* Boiss. Anales Jardín Botánico de Madrid, 53 (1): 5-12.

AUSSENAC G., 2002. Ecology and ecophysiology of circum-Mediterranean firs in the context of climate change. Annals of Forest Science, 59 (8): 823-832.

BARBEY A., 1931. À travers les forêts de pinsapo d'Andalousie. Étude de dendrologie, de sylviculture et d'entomologie forestière. Paris, France, Librairie Agricole, 110 p.

BLANCA G., 1993. Origen de la flora andaluza. Consejería de Cultura y Medio Ambiente, Junta de Andalucía, Sevilla, Spain, 19-36.

BOCQUET G. B., WIDLER B., KIEFER H., 1978. The Messiniam model. A new outlook for the floristics and systematics of the Mediterranean area. Candollea, 33: 269-287.

CEBALLOS L., MARTÍN BOLAÑOS M., 1928. El abeto de Marruecos. Una excursión al monte Magó. Madrid, Spain, Real Sociedad Española de Historia Natural, Tome III, N. 1 & 2. 11 p.

CEBALLOS L., MARTÍN BOLAÑOS M., 1930. Estudio sobre la vegetación forestal de la provincia de Cádiz. Madrid, Spain, IFIE, 353 p.

CEBALLOS L., RUIZ DE LA TORRE J., 1979. Árboles y arbustos de la España Peninsular. Madrid, Spain, ETSI Montes, 521 p.

CEBALLOS L., VICIOSO C., 1933. Estudio sobre la vegetación y la flora forestal de la provincia de Málaga. Madrid, Spain, IFIE, 285 p.

FARJON A., 1990. Pinaceae. *Abies, Cedrus, Pseudolarix, Keteleeria, Nothotsuga*. Königstein, Swiss, Koeltz Scientific Books, 330 p.

FLOUS F., 1936. Classification et évolution d'un groupe d'abiétinées. Trav. Lab. Forest. Univ. Toulouse, France, 1 (2), art. XVII.

GARCÍA LÓPEZ J. M., 1993. Paleogeografía del género *Abies* en el Mediterráneo. Madrid, Spain, ETSI Montes, Dpto. Silvopascicultura, 19 p.

GAUSSEN H., 1964. Les gymnospermes actuelles et fossiles. Trav. Lab. Forest. Univ. Toulouse, France. Fasc. VII. 321-480.

JEANMONOD D., BOCQUET B., 1981. Remarques sur la distribution de *Silene nollisima* (L.) Pers. et des espèces affinées en Méditerranée occidentale. Candollea, 36: 279-287.

LIU T., 1971. A monograph of the genus *Abies*. Taipei, Publ. Depart. Forestry. College of Agriculture, Taiwan University, Taiwan, 608 p.

PARDUCCI L., 2000. Genetics and Evolution of the Mediterranean Abies species. Thesis, Swedish University of Agricultural Sciences, Sweden, Umea, 148 p.

PASCUAL L., GARCÍA F.J., PERFECTTI F., 1993. Inheritance of isozyme variations in seed tissues of *Abies pinsapo* Boiss. Silvae Genetica, 42 (6): 335-340.

PERAZA C., 1964. Estudio de las maderas de coníferas españolas y de la zona norte de Marruecos. Madrid, Spain, IFIE, 112 p.

PRIOTON J., 1964. Plaidoyer pour le sapin d'Espagne. Revue Forestière Française, 2: 99-114.

SÁNCHEZ CÓZAR S., 1946. El *Abies* del Tazaout. Revista de la Real Academia de Ciencias de Madrid, Spain, tome XL, 449-468.

SCALTSOYIANNES A., TSAKTSIRA M., DROUZAS AD., 1999. Allozyme differentiation in the Mediterranean firs (Abies, Pinaceae). A first comparative study with phylogenetic implications. Pl. Syst. Evol., 216: 289-307.

VICARIO F., VENDRAMIN G. G., ROSSI P., LIO P., GIANNINI R., 1995. Allozyme, chloroplast DNA and RAPD markers for determining genetic relationships between *Abies alba* and the relict population of *Abies nebrodensis*. Theoretical and Applied Genetics, 90 (7-8): 1 012-1 018.