“ANALYSIS OF THE OAK DECLINE IN SPAIN; *LA SECA*”

Bachelor Thesis in Forest Management
Clara González Alonso
Supervisor: Tord Johansson
“Swedish University of Agricultural Sciences”
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• INTRODUCTION

Over the last few decades, million of trees have been affected by a complex disease known as oak decline, oak dieback or oak mortality, depending on the area and the particular case taken into consideration. In Spain has been named *"la seca"* and it refers to the decline and death of individuals of the Quercus species, especially around the Mediterranean region.

Since the beginning of the 1980s, the Iberian Peninsula has experienced an evident increase in the spread and frequency of this disease and consequently, in the damages caused by it (Herranz, 2004; Cobos *et al*., 1993; Brasier, 1996; Arias and Del Pozo, 1997; Moreira et al., 2006). For these reasons, also more efforts have been made by experts and researchers in order to determine the causes, characteristics and possible treatments to slow down this process.

The complexity of this disease is based on the difficulties that scientists face when they try to find and define the factors causing and leading the decline process. There is not only one cause nor one unique development for the disease. There are a lot of interacting factors influencing over each particular situation and this fact makes difficult the search for explanations and possible solutions to the problem.

The principle aim of this work is to collect information about this complex disease being focus in the particular case of Spain. Spain is a country where this disease has special importance. The *Quercus* genus is widely spread in the region and consequently, damages in the oak forests represent important ecological and economical losses. The climatic characteristics and the specific site conditions of the country, mark this case with its own distinctiveness and particularities. The past and current situation of Spain trying to face this problem is analyzed. It is shown that big efforts are made in this country to deal with this phenomenon that is threatening one of its most appreciated kinds of forest.

For the study of the oak decline, the main factors linked to this phenomenon are described and also possible actions that could be carried out by humans in order to improve the current situation are presented. Special attention is paid to the parasitic factors involved in the oak decline process, but other related factors are presented too in order to have a complete overview about the problem.

• THE ROLE OF *QUERCUS* GENUS IN SPAIN

The *Quercus* genus has historically been always present in Spain and the rest of the Iberian Peninsula playing a fundamental role in this region. According to FLORA IBÉRICA, 25 out of the about 300 species belonging to this genus, are considered as spontaneous species growing in Europe, and ten of them are native in the Iberian Peninsula (Franco, J.A. in Castroviejo & al., 1990). These species are quite varied in terms of morphology and they have the possibility of hybridize easily. These are the ten species considered as native in the Iberian Peninsula by FLORA IBÉRICA:

- *Quercus robur* L.
- *Quercus petraea* (Mattuschka) Liebl.
- *Quercus humilis* Miller
- *Quercus pyrenaica* Willd.
- *Quercus faginea* Lam.
- *Quercus canariensis* Willd.
- *Quercus lusitanica* Lam.
- *Quercus suber* L.
- *Quercus ilex* L.
- *Quercus coccifera* L.

Quercus ilex (holm oak) and *Quercus suber* (cork oak) are the main species of the genus present in the peninsular Spain. They are found growing in large extensions in the autonomies of Andalusia, Extremadura, Castilla-León, Castilla-La Mancha and Madrid, being *Quercus ilex* commonly dominant over *Quercus suber*. Only taking into account the forests composed by these two species, they occupy approximately 10% of the total area of the country (Tuset, J.J. et al, 2006). Thus, the ecological importance of these formations is unquestionable, specially having in mind that about 50% of the total area of the country is covered with agricultural lands (Soriano Martín et al, 2004). Moreover, they are also quite relevant from an economic and social point of view, especially when they constitute *dehesas*, an agrosilvipastoral exploitation characteristic of the region. It is obvious then, that *la seca* is affecting some of the most important forests in Spain.

Source: Fundación interuniversitaria Fernando González Bernáldez.

- DISTRIBUTION OF THE SPECIES

Approximately half of the 50% of the Spanish area which is not dedicated to agriculture is covered by scrub, esparto grasslands and other grasslands. The remaining percentage is occupied by broadleaves (29%), aciculate (40%) or mixed stands (31%). (Soriano Martín et al, 2004).

The *Quercus* genus is spread over all the regions in the Iberian Peninsula. Due to the capacity of vegetative reproduction of most of the species within this genus together with the fact that these species have been traditionally used for obtaining firewood, in many cases, stands formed by shrubs of these trees have been conserved. All these low forests plus the *dehesas* and other open woodlands dominated by individuals of this genus, represent the most important part of the remaining stands we find nowadays. We can assume that currently, there is not any forest of *Quercus* in Spain which remains directly or indirectly untouched by humans (Soriano Martín et al, 2004).

Giving a broad overview, the most important forests of the genus are established in the center and south-west of the country where paradoxically, the worse cases regarding oak decline have taken place, affecting both isolated trees as well as grouped individuals (Brasier et al., 1993, Cobos et al, 1993).

Distribution maps for the ten native species in the Iberian Peninsula are presented below. All of them are modified versions from the original *forest map of Spain* (Mapa forestal de España) by Ceballos (1960), elaborated by Soriano Martín et al. (2004). They only reflect where each of the species is found forming extent stands.

- *Quercus robur* L.:

  According to Flora Iberica, this species is present in the following provinces (See appendix with map of the Spanish provinces):

  - All provinces in Galicia
  - Asturias
  - Cantabria
  - All provinces in País Vasco
  - Navarra
  - All provinces in Cataluña (except Tarragona)
  - Salamanca, Zaragoza, León, Palencia and Burgos in Castilla-León
  - Madrid

Fig.1 . Distribution of Quercus Robur stands in Spain by Soriano Martín et al. (2004).

- *Quercus petraea* (Mattuschka) Liebl.:

  According to Flora Iberica, This species is present in the following provinces (See appendix with map of the Spanish provinces):

  - All provinces in Galicia (except Pontevedra)
  - Asturias
  - Cantabria
  - All provinces in País Vasco
  - Navarra
  - All provinces in Cataluña
  - Cuenca
  - All provinces in Aragón (except Teruel)
  - Zaragoza, león, Palencia, Burgos, Segovia and Soria in Castilla-León
  - La Rioja
  - Madrid

Fig. 2. Distribution of Quercus petraea stands in Spain by Soriano Martín et al. (2004).

- *Quercus humilis* Miller:

  According to Flora Iberica, This species is present in all the provinces of Spain <u>except</u> the following ones (See appendix with map of the Spanish provinces):

  - All provinces in Cataluña
  - All provinces in País Vasco
  - All provinces in Aragón
  - La Rioja
  - Navarra
  - Mallorca in Islas Baleares
  - Soria

- *Quercus pyrenaica* Willd.:

  According to Flora Iberica, This species is present in all the provinces of Spain <u>except</u> the following ones (See appendix with map of the Spanish provinces):

  - Huesca
  - Lérida
  - Barcelona
  - Gerona

- Alicante
- Murcia
- Almería

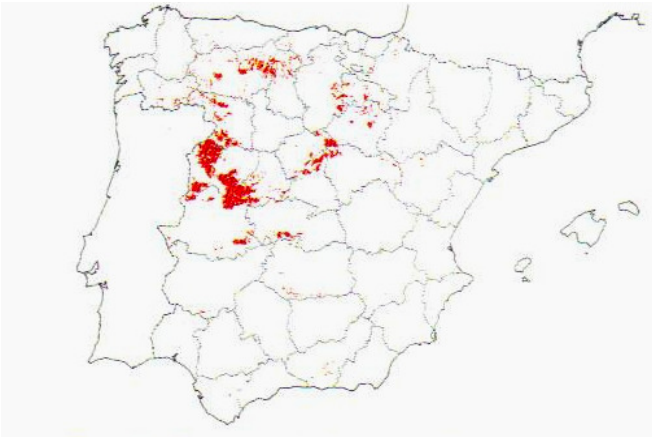

Fig.3 . Distribution of Quercus pyrenaica stands in Spain by Soriano Martín et al. (2004).

- *Quercus faginea* Lam.:

  According to Flora Iberica, This species is present in all the provinces of Spain <u>except</u> the following ones (See appendix with map of the Spanish provinces):

  - La Coruña, Lugo and Pontevedra in Galicia
  - Guipúzcoa in País Vasco

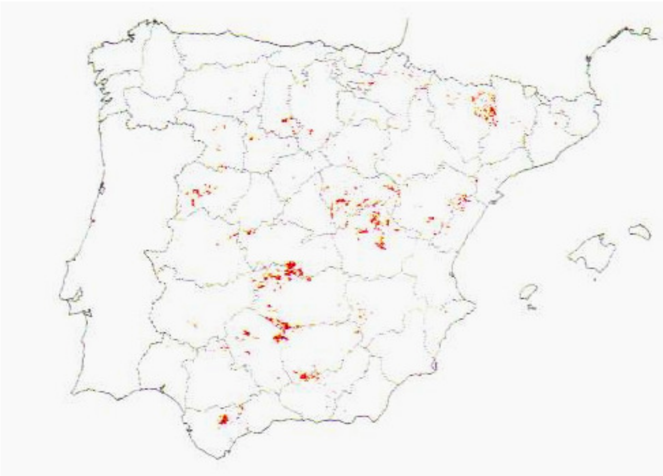

Fig.4 . Distribution of Quercus faginea stands in Spain by Soriano Martín et al. (2004).

- *Quercus canariensis* Willd.:

  According to Flora Iberica, This species is present in the following provinces (See appendix with map of the Spanish provinces):

  - Huelva, Cádiz, Sevilla and Málaga in Andalusia.
  - Ciudad Real in Castilla – La Mancha
  - Barcelona in Cataluña

Fig.5 . Distribution of Quercus canariensis stands in Spain by Soriano Martín et al. (2004).

- *Quercus lusitanica* Lam.:

  According to Flora Iberica, This species is present in the following provinces (See appendix with map of the Spanish provinces):

  - Huelva, Cádiz, Málaga in Andalusia
  - La Coruña (very rare)

- *Quercus suber* L.:

  According to Flora Iberica, This species is present in the following provinces (See appendix with map of the Spanish provinces):

  - All provinces in Galicia
  - Cantabria
  - All provinces in País Vasco
  - León, Zaragoza, Salamanca and Ávila in Castilla-León
  - Madrid
  - Toledo, Ciudad Real, Albacete and Gualadajara in Castilla- La Mancha
  - All provinces in Extremadura
  - All provinces in Andalucía
  - Murcia

- Valencia and Castellón in Comunidad Valenciana
- Zaragoza
- Barcelona and Gerona in Cataluña
- Menorca in Islas Baleares

Fig. 6. Distribution of Quercus suber stands in Spain by Soriano Martín et al. (2004).

- *Quercus ilex* L.:

  According to Flora Iberica, This species is present in all the provinces of Spain <u>except</u> the following ones (See appendix with map of the Spanish provinces):

  - La Coruña and Pontevedra in Galicia

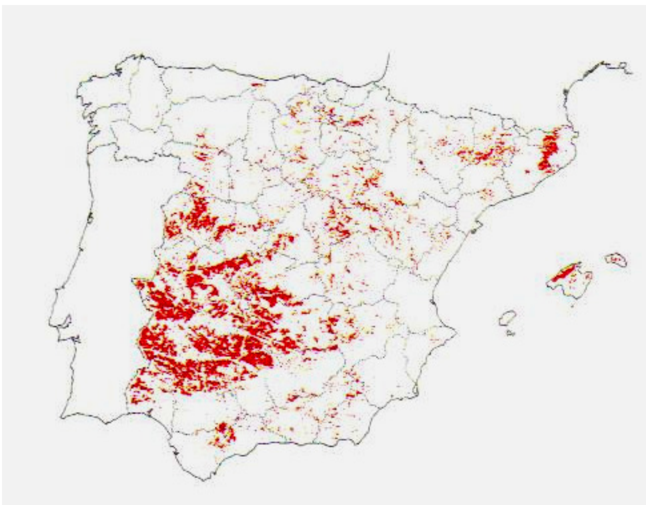

Fig. 7. Distribution of Quercus ilex stands in Spain by Soriano Martín et al. (2004).

- *Quercus coccifera* L.:

  According to Flora Iberica, This species is present in all the provinces of Spain <u>except</u> the following ones (See appendix with map of the Spanish provinces):

  - All provinces in Galicia
  - Asturias
  - Cantabria
  - Vizcaya
  - Guipúzcoa
  - León, Salamanca, Palencia, Valladolid, Ávila and Segovia in Castilla-León

MANAGEMENT AND EXPLOITATION OF *QUERCUS* FORESTS

Within the Spanish *Quercus* forest, two different basic forest management systems derived from the application of two different regeneration methods have traditionally existed. On the one hand, there is a type of high forest with scattered trees which is commonly exploited as an agrosilvopastoral system. Most of these forests constitute the overcalled *dehesas*. On the other hand, it can be a coppice system or low forest derived from the use of the forest for production of firewood, charcoal or bark for tanning pelt.

The first type of *Quercus* forest is usually developed in warmer areas, frequently counting with high yields of acorns, while the second type is found in colder and more continental areas, producing lower yields of acorns but good quality and quantity of firewood and charcoal. Between these two distinguished types of forest, there are some *dehesas* which gather characteristics from both extremes regarding management by humans and which environmental and economic conditions are also intermediate.

- **High forests: *dehesas***

Most of the *Quercus* forests where sexual reproduction by seeds predominates over asexual reproduction are forming *dehesas* throughout the Spanish countryside. The *dehesa* system probably appeared during Neolithic period, although the first written reference is from 924 (Olea et al., 2005). Its evolution and expansion was linked to historical events such as the reconquest of the Iberian Peninsula from the Moors, the role of the Mesta (powerful association of stock holders in the medieval Kingdom of Castile) and the sale of Church and nobility lands. Nowadays, the *dehesa* is a system protected by the European directive 92/43/EEC (Habitat Directive) and it is included in the Nature 2000 network.

These systems are usually mentioned as silvopastoral systems where trees and grazing animals are combined in the same unit. However, some *dehesas* are actually agrosilvopastoral systems because crops, grazing animals and trees are present in the same plot. Every element of a *dehesa* has to be properly managed for making the system sustainable in all senses.

Fig.8 . Dehesa in Cáceres province, Extremadura.
Source: The Encyclopedia of Earth, Martin Holzer

Due to the existing heterogeneity within the different *dehesas*, it is clear that their management will be also quite different being influenced by the elements forming the system, the characteristics of the site, the exploited products…etc. For instance, it is not the same to manage a *dehesa* for producing high quality cured ham than a *dehesa* which exploits cork production. However, some generalities about management of *dehesas* are presented in this section.

In a typical *dehesa,* a characteristic tree layer with scatter individuals of the same *Quercus* specie forms the stand. The trees play an important role maintaining the stability of the system and they have an important influence over the landscape, soil conservation and water and nutrients cycles. The density of the tree layer is a crucial factor which is determined attending to the specific characteristics of the site and the composition of the forest. Usually, it varies between 20 and 100 adult trees per hectare. The optimal density also depends on the benefits that are obtained from a particular *dehesa*, but it is generally between 50-60 trees/ha (Fernández et al., 1998). In the particular case of cork oak forests, they are usually managed so that cork harvest is done almost every year in different trees dispersed in the stand, creating a patchy pattern of mixed aged cork trees (Serrão, 2002).Generally, it seems that at present the density in many *dehesas* is decreasing, probably due to the lack or shortage of natural regeneration. The main direct products obtained from the tree layer are firewood, browse, acorns and cork.

However, the extensive livestock is usually the most important direct product of the *dehesa*. If the management is adequate, the animals are also an important tool for creating and improving natural and sown pastures and for dispersing their seeds and increasing soil fertility. Carrying capacity of a certain site must be considered and respected. In many cases, excessive grazing by the animals compromises the regeneration and stability of the tree layer. This will cause economic losses and environmental damages. Very different decisions must be taken depending on the type of animal grazing in the *dehesa* which are commonly cattle, sheep, swine (Iberian pig), goat, horses or donkey.

It is worth mentioning that since 1960's it is increasing the importance of the *dehesa* as hunting areas. Hunting species have always been present in the dehesa system, but the cynegetic carrying capacity must be strictly considered. Sometimes, the owners fence their properties causing a dramatic increase of wild ungulate densities that are threatening the sustainability of the system.

Natural pastures are the main source of fodder for livestock. That is probably why this layer is often managed for improving the efficiency of the system. Moreover, in some of *dehesas,* cropping is carried out every 2-5 years. In this way, crops can provide enough food for livestock or/and humans and at the same time this cultivation contributes to the control and management of the herb layer.

Fig. 9. Dehesa where holm oaks and crops are combined. Picture taken in Segovia, Castilla y León, by Clara G. A.

- **Low forest: coppice systems**

In this kind of *Quercus* forests, asexual reproduction by shoots and suckers predominates over the sexual reproduction. Traditionally, the product which is most commonly exploited from these systems is firewood. This product has been used directly for burning or for producing charcoal. The harvested wood is classified according to the size of each collected piece. Usually, there are four different categories of firewood which prices and final use differ considerably.

Fig.10 . Traditional production of charcoal in La Rioja.
Source:ojodigital, 2006

Short rotation periods are usually defined for this kind of exploitation where small dimension firewood is obtained after every harvest. Frequently, the cutting age is no higher than ¼ of the typical cutting age fixed for a high forest of the same specie. Field portions with different ages and similar production are managed inside each plot. In this way, the quality and quantity of firewood obtained every year is quite similar. If the clear cuttings are carried out too frequently, the stools will get weak and the firewood obtained will have smaller dimensions. On the contrary, if the rotation period is too long, the number of stools will be smaller and they will produce firewood which dimension could be excessive.

Some other small treatments can be applied during the rotation period. Occasionally, each stool is partially cleared and only the best shoots are kept untouched in order to favor its growth. When livestock is also present in the system, it is convenient to enclose the recently cleared cut area until the new shoots and suckers reach certain size. This size depends on the type of livestock grazing on the area. For instance, the young shoots will be resistant to damages caused by sheep earlier than if the damages were caused by cows.

In a few regions of Spain like Cataluña, some low forests of *Quercus* are exploited in two steps. In a first step, only the biggest shoots of each stool are harvested, allowing the smallest shoots to grow better. There is consequently a second harvest where the remaining shoots are collected. This kind of management turns out in a higher protection of the soil against erosion, but not all the *Quercus* species can endure this way of harvest.

Nowadays there is certainly an increasing interest in using biomass from *Quercus* forests for producing bioenergy. In this case, even shorter rotation periods should be fixed. Since there would be no limitation regarding size of the obtained wood pieces, all the biomass of each tree could be used in a stand managed in this way.

Finally, it is important to mention that in the last decades, traditional silvicultural practices in both high and low forests of *Quercus* have been abandoned in some extent. Prices of firewood and charcoal started decreasing in 1964 (Montoya and Mesón, 2004). This fact explains part of the occurred changes regarding *Quercus* forests management and exploitation. At the same time, number of people living and working in the countryside, for this and other reasons, is getting lower and lower with time. Thus, today there is a lack of qualify workers knowing how to perform many traditional and absolutely necessary works which are required for the maintenance and success of the system. The clearest case is the exploitation of *Quercus suber* stands for obtaining cork. The collection of cork has to be done manually by good professionals because is a really delicate practice. If new generations stop learning this practice from the previous ones, then production of cork will not be viable anymore.

• OAK DECLINE AROUND THE WORLD

Even thought this work is focused on the problem in Spain, the decline of the *Quercus* genus is not a local problem exclusively spread throughout the Iberian Peninsula. Internationally, *la seca* is commonly named 'oak decline' and as in Spain, it has been recorded and studied since the first patent outbreaks during the eighties (Brasier et el., 1993; Cobos et al., 1993).

According to Luisi et al. (1993), over the last few decades oak decline has affected millions of trees in the northern hemisphere, particularly in Europe, United States and Asia. It was in Germany where the disease was first reported as early as 1739. But it was not until the 1980s when the cases started to be reported with a worrying frequency all around the world (Cobos *et al*., 1993; Brasier, 1996; Herranz, 2004; Moreira et al., 2006; Moreira et al., 2004).

The increase in the worry and concern about the disease, turned out in a great amount of meetings, studies, projects and investigations carried out simultaneously all around the word. Thus, we can mention among the international meetings and congresses about oak decline, “Recent Advances in Studies on Oak Decline” occurring in Brindisi, Italy in 1992, “Oak decline in Europe” celebrated in Kornik, Poland in 1990, as well as the “Ad hoc meeting on oak decline” by the European and Mediterranean Plant Protection Organization (EPPO) in 1990 (Muñóz et al., 2003).

Reports of 11 European countries on oak decline presented at an EPPO *ad hoc* Panel meeting at Lillafüred (HU) on 1989–06–20/22 showed that most of the countries (Austria, Czechoslovakia, Germany, Hungary, Italy, Netherlands, Poland, Yugoslavia, Spain, Portugal) recorded significant oak decline in the 1980s. In France, periods of decline mainly occurred earlier in the century, and only local decline was seen in the 1980s. In the United Kingdom, decline has not been considered a big problem and only local dieback have been observed (Robin et al., 1998). Since the beginning of the 1990s, Swedish oak forests have experienced a dramatic deterioration in health (Sonesson and Anderson, 2001).

One can observe how the European view about oak decline has changed in some years. In the beginning on the 90’s it was only considered as an episodic phenomenon of local or regional importance, but nowadays has been understood that it has been going on since the beginning of the 1980s and now is occurring all over Europe (Delatour 1983; Hartmann et al., 1989; Siwecki & Liese, 1991; Luisi et al., 1993).

Thus, nowadays it is evaluated as a serious and frequently occurring disease affecting the oak forests (Delatour, 1983; Oleksyn and Przybyl, 1987; Hartmann et al., 1989). Some authors as Alessandro Ragazzi (2002), or Salvatore Moricca (2002), have considered the situation of the last 15 years in Europe as dramatic. The most frequently affected species in Europe seem to be *Quercus robur* and *Quercus petraea* (Jung, T. et al., 2000; Alessandro R. et al., 2001). Some of the decline symptoms which are common to all cases in Europe are thinning, growth of epicormic shoots and bleedings.

Regarding to the studies carried out by the different experts of each country, it is understandable that there are some differences among the conclusions drawn about the factors involved in the disease. One of the factors which has been more study and presented as a key agent involved in the disease is the presence of *Phytophthora* species on the forest soil. Thus, in France they usually defend that this is the principle cause of the decline (Delatour et al., 1998; Robin et al., 1998). Also in Mexico, research identifies the root pathogen *Phytophthora cinnamomi* as the primary cause of mortality (Tainter, et al. 2000). In Portugal many authors as Moreira and Martins (2004), support this idea too and their studies are usually focused on *Quercus suber* stands. In Germany, important studies have been also carried out to investigate *Phytophthora* species in the soil of affected stands (Jung et al., 2000). Also studies in Southern Sweden point out that *Phytophtora quercina* is geographically widespread in oak stands in southern Sweden and indicate that this pathogen may be one of the factors involved in oak decline in Northern Europe (Jönsson et al., 2003). In Austria and India, also important results finding *Phytophtora quercina* as a key factor have been shown (Balci et al., 2002). Italy has dedicated some studies to increase the knowledge about different *Phytophthora* species (Ragazzi et al., 2001). However, many researchers support that the characteristics of the physical environment, for example compression of soils among others, determine the incidence of the disease (Luisi et al., 1993).

Lately, many researchers have started investigations on bacteria, such as *Brenneria quercina,* to clarify the importance of its role in the disease process. The first study focused on this pathogen was performed in the United States (Hildebrand et al., 1967), it was followed by many other studies all around the world, for example in

United Kingdom (CMI, 1981), Spain (Biosca et al., 2003; González et al., 2002; Poza Carrión et al., 1999) or Italy (Scortichini et al., 1992).

However, it is still clear than any of the implied countries has a unique opinion about the factors responsible for the disease. Year after year, new investigations focus on particular damaging agents increase the understanding of the decline process, but nearly all the authors and researchers agree on the affirmation that oak decline only takes place when several of these pathogens co-occur in a certain site (Tuset et al., 2006).

• HISTORICAL EVOLUTION OF *LA SECA* IN SPAIN

As in many countries all around the world, in Spain the term of oak decline or *la seca* has been used since the 1980s to point out the decline and death that different species belonging to the *Quercus* genus are suffering. In the Iberian Peninsula the species being more frequently affected by this disease are *Quercus Ilex* L. (holm oak) and *Quercus suber* L. (cork oak) (Brasier, C. et al., 1993 and Tuset, J. J. et al., 2002). Probably *la seca* is an oldest problem than we think, but what we know is that there was not such a high number of death trees every year before the eighties.

In the end of the 80s decade, the problem was so extended throughout the Spanish forests that people got concerned about the situation and some group works were created to study the disease and act against it. From the government, specifically from the Administration of the Estate, one of these groups was born and was in charge of coordinating the activities carried out by the forest and phytopathological services at each of the 17 Autonomous Communities of the country. The aims of this initiative were to evaluate the problem, analyze its causes and try to find some strategies to alleviate the consequences of the syndrome. At the same time, some studies, in specific sites where the disease was more developed, started. Some research teams where responsible for these studies and other parallel investigation projects were financed by national and communitarian founds.

As a result of these years of work, the government stated that every holm and cork oak forests in the Peninsula were affected by *la seca* except the ones in the Cantabric cornice, in the North of Spain (Tuset, J.J et al., 2002).

Since then, many works and researches have been carried out from different points of view, turning out in the statement of diverse hypothesis regarding the origin of the disease. The first and more accepted idea about its origin was the consideration of hydric stress caused by periods of drought as the primary cause of the syndrome. Climate change was also nominated as the main cause provoking the disease, and also certain damaging organisms as *Phythopthora cinnamomi, Brenneria quercinea* or *Botryosphaeria stevensii* among some others. However, even many of the presented hypotheses could separately explain the mortality of the trees, none of them completely justify it, because they do not appear in every case.

The necessity of canalizing the efforts of the different groups involved in the study of the causing factors of *la seca* and in the searching of partial or global solutions to the problem was evident. As a consequence, a common project was elaborated and published under the name of “Causas del decaimiento y *Seca* de las masas de *Quercus* mediterráneos. Técnicas de amortiguamiento” (“Causes of the decline and *seca* of the Mediterranean *Quercus* forests. Mitigation techniques”). Research groups from Andalusia, Aragon, Catalonia, Extremadura, Madrid and Valencia collaborate during the years 1999, 2000 and 2001.

This project gathered a lot of valuable knowledge that was dispersed before its completion. A good advantage derived from this work was the establishment of a classification of *la seca* attending to the factors involved in its origin and the symptoms linked to it. With this classification it is already possible to differ among natural deaths, deaths caused by a deficient silviculture, by a parasite or by drought and other unfavorable climatic processes.

Summing up, nowadays it is know that almost every forest of the *Quercus* genus in Spain has been affected by *la seca* to some extent. The disease seems to be more evident in the forest consists of holm oak and cork oak growing in the central region and in the south west of the country, but each forest of the Peninsula is threatened by this complex syndrome that does not stop in its spreading and evolution.

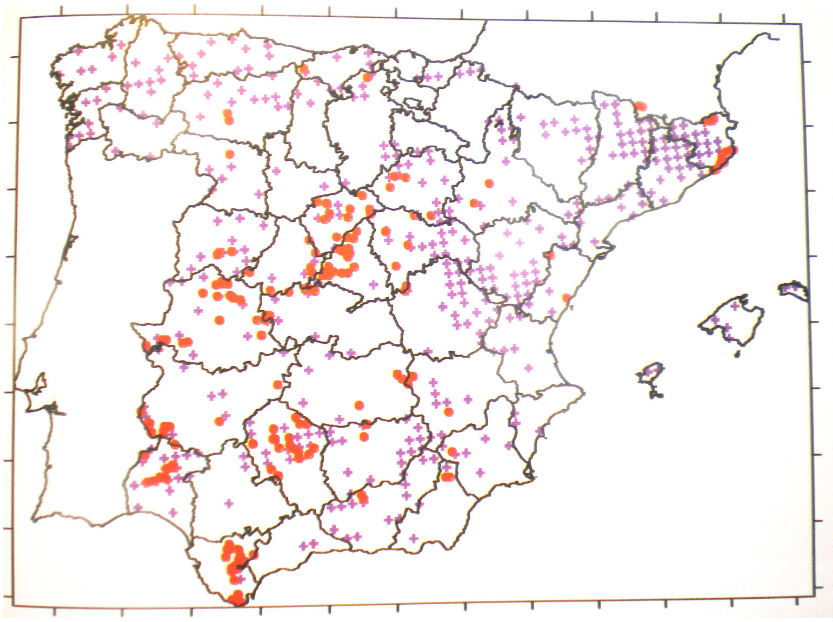

Fig. 11. Representation of points where the 'European net of damages monitoring in Spain' is working. The red dots are the points where the presence of la Seca has been reported. Map elaborated by Fernández Cancio et al. (2004)

The origin of the disease is still uncertain and the future control of it is not clear yet. During the last decades big efforts have been made to study the situation and thanks to that, today we know quite a lot about the symptoms and the factors affecting the phenomenon. It is clear than the research must go on and the possible techniques and treatments of mitigation and prevention should be more actively implanted. Since *la seca* is, after all, a natural process where many different factors are interacting, probably it is not possible to stop the decline completely. However, it is always possible to reduce and control in some extent the negative effects of the disease by conducting our actions towards the right direction, taking into account both human and natural benefits.

• DESCRIPTION OF THE OAK DECLINE PROCESS; "*LA SECA*"

The name of *la seca* designates a group of symptoms where many different parasitic agents can be involved, giving rise to a process of quick devitalization which follows no defined patterns during its development and expansion. At the same time, determining factors of the environment, such as climatology and soil, play a fundamental role that drives this process. Silvicultural management, or rather the lack of this activity, also contributes in the dynamic of the process.

Since the factors determining this disease are so diverse, obviously the symptoms characterizing the process over the affected trees are equally diverse. Some of the damaged individuals experience a sudden death of the whole tree while others just experience a slow and progressive decline that can last for several years.

However, there are some general symptoms that can be found almost in every case. On one hand, the slow decline marked by the gradual fall of the foliage and the presence of branches partially or totally defoliated. On the other hand, the sudden death of twigs and leaves which remain adhered to the tree during some time giving to the canopy a peculiar brownish coloration.

Fig. 12. Holm oak where loss of foliage can be noticed.
Picture taken in "El Monte del Pardo", Madrid by Clara G.A.

The term 'sudden death' is used when a tree which is apparently healthy and it does not present patent symptoms of decay, dies in a short period of time. When the tree does present symptoms of decay but it can remain alive for one or more years, it is suffering from a 'progressive decay'. The process of 'devitalization' associated with *la* seca make reference to the survival of the stand during a longer period of time even thought its health is very limited.

There is not a defined pattern for the spatial distribution of the symptoms in a stand. Thus, healthy, weak and death trees cohabit in the same ecosystem. Other factors as the age or shape of the trees do not seem to have any clear influence.

Among the most common symptoms of decay, it is important to mention the apparition of cankers whose exudations get subsequently dark. This fact dyes the wood and bark with a characteristic jet-black color. Sometimes these cankers are developed in the inner bark, so there is only a small dark area visible from the outside. In addition, the damaged trees can present checks or oozes in the bark resulting in dark marks that can be quite conspicuous.

The incidence of the phenomenon of *la seca* is usually reactivated periodically in a stand. Particularly in Spain, this periodicity is related to the thermal increase taking place during the months of July and August. When there is a long dry period this reactivation also occurs.

• POSSIBLE FACTORS LINKED TO OAK DECLINE

In an attempt of improving the understanding of the complexity of the oak decline disease, the main factors considered as key factors affecting the process are presented in this section. The implied factors are organized in three big groups: biotic, abiotic and silvicultural factors. The information gathered about each factor is only focused on damages or influences over oaks, but it does not explain the implications of each factor in other ecosystems.

o BIOTIC FACTORS

Once the process has started is relatively easy to find different biotic agents, most of them clearly opportunist, such as fungi belonging to the *Phypthopthora* and *Diplodia* genus, together with defoliators and wood boring insects and bacteria among other pathogens. The result of their parasitism is a process of serious decline and, in many cases it can also entail the death of trees or stands in a relatively short period of time.

▪ INSECTS

Many insects find in oaks suitable niches for feeding and/or living. Some of these species are considered as pest individually, while others can only be a threat for the trees when acting simultaneously with other pathogenic agents or coinciding with some stress conditions. Several studies have pointed out that insects, particularly defoliators, can play an important role triggering the outbreaks of decline and in the development of the process (Thomas et al., 2002). However, generally they are not individually considered as responsible for the death of oaks. Distributions of the species are quoted from the book *"Plagas de insectos en las masas forestales"* coordinated by Romanik and Cadahia (2003).

- Leaf feeders:

Defoliators insects reduce in different extend the foliage of the affected trees. The mechanical damage produced by these insects, will have important physiological consequences. The loss of leaf area turns out in a lower photosynthetic rate. This results in a decrease of the stored carbohydrates and consequently in the production of new buds which could replace the lost foliage. These damages on buds and leaves are mainly caused by lepidopterans belonging to the family *Tortricidae.*

- *Tortrix viridana* L.

The commonly named 'European oak leafroller' or 'the green oak moth' is found all around Europe, north of Africa and west of Asia;

Germany, South of Finland, Sweden, Norway, France, Portugal, Spain, Italy, Asia Minor, Russia and Morocco. It prefers low regions, although it can tolerate altitudes up to 1.100 meters. Within Spain, it is found almost at every province where oak stands grow, being of special importance in the south-west of the country.

Fig.13 . Caterpillar of Tortrix viridana L.Taken in a Q. ilex stand in "El Monte del Pardo", Madrid by Clara G.A.

The most attacked tree species by this defoliator in Spain are *Q. ilex, Q. suber, Q. faginea* (Quejigo oak) and *Q. pyrenaica* (Pyrenean oak). It has been one of the most serious pests for holm oak stands. It feeds on buds, consequently reducing the production of acorns every year. According to Romanik et al. (2003), losses of several millions of euros are caused by this insect in holm oak forests.

- *Lymantria dispar* L.

This specie is also known as "gypsy moth" and it is clearly polyphagous. It was originally spread out throughout Europe, Asia and North of Africa but it was introduce to North America in the late 1860's (Liebhold, 2003). It has cause important damages as a pest in the Mediterranean region.

Particularly in Spain, it is more often affecting holm and cork oaks, although it can also feed on other *Quercus* like, *Q. faginea, Q. pyrenaica* and on other broadleaves and even some conifers. When densities reach very high levels, trees may become completely defoliated. Consequently, the subsequent growth of the damaged trees is really slow or nearly null. Obviously, the production of fruits decreases too. However, only when several successive years of defoliation occur, along with contributions by other abiotic and biotic stress factors, this pest can result in tree mortality.

The influence of *L. dispar* on cork oak is well known. Just as in holm oaks, it causes defoliation which induces a reduction in acorns production. In addition to this, it also influences over the cork growth and quality and increases the difficulty of its extraction (Serrão, 2002). Fortunately, in some cases the natural enemies of *L.dispar* present at the site help with the control of the population of this defoliator between certain admissible limits.

Fig. 14. Fifth instar gypsy moth larva. Source: US forest service

- *Malacosoma neustria* L.

This other polyphagous specie is also called 'lackey moth' and the caterpillars feed on leaves causing notable defoliations. It is distributed almost all around Europe, being present in all the Iberian Peninsula. It is always associated with *Tortrix viridana,* especially in the south west oak forests managed for production of acorns. The most important damages have been recorded in the north west of Huelva (Andalucía) and in the south west of Badajoz (Extremadura).

Damages are caused by the caterpillars which defoliate the host tree where they establish. When affecting holm oak, they feed on tender leaves respecting, in most of the cases, the new buds and consequently, the future female flowers. Thus, the acorn's production is not as seriously affected as it is by other insect pests. It also attacks other oaks in Spain, besides holm oak, causing similar damages.

Fig.15 . Caterpillar of Malacosoma neustria L.
Picture taken in a Q. ilex stand in "El Monte del Pardo", Madrid by Clara G.A.

- *Catocala nymphagoga* Esp. and *Catocala nymphaea* Esp.

These two lepidopterans are usually found affecting oak stands simultaneously and they are commonly named 'underwings'. The caterpillars and the moths of both species develop and live together, in mixed groups. They are typically Mediterranean and Asiatic species. In the Iberian Peninsula they are widely spread out, having records from Almería, Ávila, Badajoz, Cáceres, Córdoba, Guadalajara, Huelva, Madrid, Murcia, Slamanca, Sevilla, Toledo and Baleares. They cause severer damages in colder regions than in warmer regions.

They feed on oak leaves, preferably tender leaves. However, they also consume old leaves when the youngest have been already eaten, especially if the caterpillars are in their last stages of development. They cause severe defoliations on oak stands and, since they are gregarious and quite voracious, it is even possible to hear the sounds from caterpillars while they feed on a partially defoliated crown.

Fig.16 . Catocala nymphagoga Esp. and Catocala nymphaea Esp moths. Source: Plant Protection Diagnostic Service

- *Euproctis chrysorrhoea* L.

The 'brown-tail' is a moth of the family *Lymantriidae* which larvae are gregarious and polyphagous. They are widely distributed all around Europe from the north of Africa till south of England, southern Scandinavia, Asia Minor, Ural, Turkestan. It has been introduced in North America where nowadays is a threatening pest.

This specie is known for being very voracious, especially during the spring. It can feed on many different tree species growing in the forests as well as on many agricultural plants. They can attack the buds, leaves and flowers of the host specie, inducing a severe defoliation and making the forests look as if a wild fire had devastated the area. It is present in *Quercus sp.* forests and several other broadleaves forests, but never in coniferous forests. They have very urticant hairs that produce discomfort or allergic reactions depending on the affected person.

- *Periclista Andrei* Konow

The larvae of this small hymenopteran induce also defoliation of some *Quercus*, being *Q. canariensis* the most susceptible specie against this particular insect. The control of this pest can be problematic because their pupae can enter in a diapause period that could last up to three years. According to Fauna Europaea (2007), it is present only in Spain, Portugal and France.

- **Wood feeders:**

In contrast with the great number defoliators that are present in the *Quercus* forests of the Iberian Peninsula, we only find a few insects feeding on the wood and bark of these trees. Most of them belong to the family *Scolitidae* and it seems that their damages, per se, cannot induce the death of any of the Spanish oaks.

- *Cerambix sp.*

Most of the drilling insects affecting oak forests in the Iberian Peninsula are either decomposers or they feed on the trunk, such as the species *Cerambyx cerdo spp mirbeki* L. and *Cerambyx welensii* K.. Nowadays, they have become a big problem for Spanish oaks, although they only cause important damages in a long term and if their attacks are followed by the presence of rot fungi (Muñóz et al., 2003).

On the other hand, it is worth mentioning that *Cerambyx cerdo* is considered as vulnerable specie by the IUCN Red List of Threatened Species (2008). It is native in Algeria, Armenia, Austria, Azerbaijan, Belarus, Czech Republic, France, Georgia, Germany, Hungary, Iran, Islamic Republic of Moldova, Morocco, Poland, Spain, Sweden, Switzerland, Tunisia, Turkey, Ukraine and United Kingdom. The most affected areas in the Iberian Peninsula are Extremadura, western Andalucía and Balearic Islands.

Fig.17 . Cerambyx cerdo by Jordi Badia
Source: Institut d'Estudis Catalan, 2009

Generally, all the *Cerambyx* species are rather big coleopterous (up to 5 centimeters long) which lay the eggs in the inner bark of the main trunk or thick branches. When the larvae are born, they start feeding on the bark and soon after, they will enter into the wood and keep feeding. Thus, they create big elliptical galleries during their development as larvae. These species usually attack decrepit or decaying trees, destroying their commercial wood and favoring its decomposition. Excessive or/and inadequate pruning of healthy oaks notably increases the susceptibility of the trees against these xylophagous species.

- *Coroebus florentinus* Herbst.

This coleopteran specie belongs to the family *Buprestidae* and it is mainly found in the circum-Mediterranean region. In Spain, it is present in all oak forests except in the ones growing in the Atlantic region. Each of the Spanish *Quercus* species can be attacked by these beetles, however, there are more records taking place in holm and cork oak forests than in any other oak specie.

The damage is caused by the larvae, which feed on the wood of branches creating circular or spiral galleries that cut the flow of nutrients and water through them and consequently, they kill that particular branch. This will turn out in a generalized weakening of the host tree that is been attacked.

- *Coroebus undatus* F.

This beetle is in the family *Buprestidae* and it is found in central and southern Europe as well as in the north of Africa. In France and Germany has been recorded affecting *Q. petraea* and *Q.robur* and in North Africa affecting *Q.ilex, Q. mirbeecki* and *Q. suber.* However, in the Iberian Peninsula has been located affecting only *Q. suber* in the Autonomies of Cataluña, Extremadura, Andalucía and in Portugal. In these regions, it causes important losses in cork production. Its larvae form galleries into the trunk, damaging the most recent layer of cork and the layer responsible for the production of new cork year after year. It generates deformities in the cork and as a result, it decreases its quality. Obviously, it also induces a loss of healthiness of the affected trees, especially important when the attack recurs for several years. Then, it will be much probable than these trees will be attack by other damaging agents.

- *Coeliodes sp.* Schönherr

These are weevils whose biology is quite complicated and not very well known. They cause damages on *Quercus* forests, being usually associated with the presence of *Tortrix viridana.* The eggs are laid on the buds, destroying them and avoiding their normal development and fructification. The lay frequently appears on the masculine aments as well. Moreover, when the buds start opening the larvae emerge and damage the new twigs, cutting them completely. Damages caused by these weevils, can be usually occurred in clusters, even though they can be scattered distributed all around the attacked forests. It is present in all Europe and particularly in Spain, they are present in all the *Quercus* stands producing acorns, but they prefer *Q.ilex* forests.

- *Platypus cylindrus* F.

This specie belongs to the family *Platypodidae* and it has been associated with sudden death in several cork oaks stands (Muñóz et al, 2003; Ferreira et al., 1989). It has been observed an unexpected explosion of *Platypus cylindrus* during the 80's and 90's in the *Q.suber* stands around the Iberian Peninsula (Debouzie et al., 2002; Muñóz et al., 2003). It seems to be related to the current oak decline affecting the entire Peninsula.

It prefers to attack decaying or death trees, so its population has been favoured by the increase of this kind of host trees in many *Quercus* stands. This fact has provoked that the numerous insects start attacking also healthy trees, due to lack of available hosts. The damages caused in cork oaks stands which cork has been recently extracted, are quite important. The adults enter into the trunks and thick branches and create complex galleries where the eggs are laid. Besides, they inoculate with fungi spores the galleries they have made, because the larvae will feed on these fungi when emerging.

- **Acorns feeders**

The production of acorns in the Spanish oak forests it is especially important due to several reasons. Firstly, damages in acorns will turn out in a worse natural regeneration of the stand. Besides, in the *dehesas* managed for production of Iberian products from pigs, acorns represent the most important source of food for obtaining the highest quality of these products.

Among the insects damaging oak fruits, we find some lepidopterans belonging to the family *tortricidae*. We can mention *Cydia fagliglandana* Zel. and *Cydia penkleriana*, which lay their eggs inside the acorns. Other insects attacking acorns are some weevils, like *Curculio elephas* Gyll. which feed on the fruit until its development is completed.

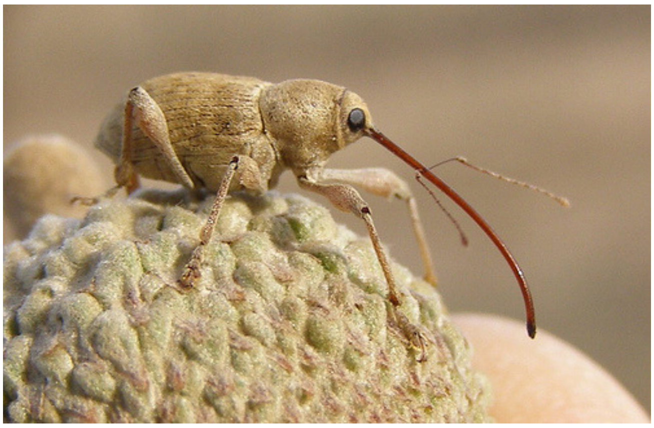

Fig .18 .Curculio elephas Gyll. By Ricardo G. Silva
Source: Flickr, 2007

- FUNGI

A great number of fungi are associated with different stages of the decay process caused by *la Seca.* In the early stages, it is common to find some fungus species which cause foliar necrosis, decreasing the photosynthetic capacity of the tree. Usually, when the trees have lost some healthiness, fungi attacking young branches and twigs are present. Thicker branches can be affected by other fungi whose fruiting bodies can often be observed. On the trunks and biggest branches, formation of basidiocarps indicates more or less advanced rot of the wood. They only appear in very decayed trees or in the ones which have been seriously harmed by inappropriate silvicultural interventions. There are also important fungi attacking the root system of the oaks. Adequate development of the roots, from the germination of the seeds, is clearly of importance for the growing of vigorous trees and their survival. In countries like Spain, where the water resources and soil conditions are usually limiting factors for the right development of the trees, a good development of the root system is especially required.

Among the numerous species that have been reported affecting oak stands in Spain, many of them were classified as saprophytic or secondary agents, only affecting already decayed or damaged trees. Some other species act as opportunistic parasites and only a few of them are actually defined as pathogenic (Luque et al., 2001). In this section the most important and frequent fungi associated with oak decline in Spain are briefly presented.

- **Leaves fungi**

- *Apiognomonia errabunda (*Anamorph: *Discula umbrinella)*

It is one of the most important foliar diseases on oaks (Muñoz et al., 2003). New buds, twigs and sprouts of infected trees shrivel and even die if formation of ringing cankers takes place. The real problem comes up when the infections recur year after year, weakening the trees and making them more susceptible against other damaging agents.

In first place, this fungus damages only the leaves, but then it can proliferate and move through the limb reaching the nervation. From there, it can arrive at the petiole and move into the young twig. This is the typical way of acting of the so called anthracnose, which is the common name for a group of diseases caused by several closely related fungi attacking the leaves and new shoots of various trees. Frequent spring precipitations and moderate temperatures favour the apparition of this fungus.

Fig.19 . Apiognomonia errabunda symptoms by Joseph O'Brien. Source: Foresty images, 2009

- *Microsphaera alphitoides*

This is an obligated parasite causing abortion of new shoots, nanism and chlorosis of the leaves which will shrivel and fall down prematurely. The mycelium density over the limbs will disturb the gases exchange processes and the chlorophyll function. This fungus preferably attacks young seedlings, so it negatively affects the natural regeneration of the stands where it is present. However, it does not cause important damages on adult trees. The most important damages provoked by this fungus in Spain have been reported in some stands of *Q. suber, Q. canariensis* and *Q. lusitanica.* However, it is present also in *Q. robur, Q. petrea and Q. pyrenaica* forests. Oaks affected by *Microsphaera alphitoides* are more vulnerable to extreme temperatures (Muñoz et al., 2003).

- *Tubakia dryiana*

This specie is a mitosporic fungus causing necrotic stains on both sides of the leaves. If the infection is severe, the originally separated stains emerge and then the whole limb, as well as the nervation, will be covered by the characteristic reddish color of the damages. The margins of the affected leaves are usually combed after some time from the first infection. It has been observed in Spain in *Q. robur stands* (Ampudia and Muñóz, 2001) causing in some of the cases severe defoliations. It is probably affecting other deciduous *Quercus* as well.

- *Trabutia quercina*

Leaves infected by this fungus, present tar spots close to the main venation of the limb. The mycelium is closely linked to the vascular system of the leaf, determining a quick alteration of the water transport process. This alteration will cause that the leaves shrivel earlier than they would under non-infected conditions. In Spain it is particularly common in *Q. faginea,* even though it has been mentioned affecting *Q. coccifera, Q. lusitanica* and *Q. ilex.* (Muñoz et al., 2003). Recently, it has been recorded in *Q. canariensis* stands (Trapero and Sánchez, 2003).

- *Spilocaea* var. *Quercus ilicis*

For the first time, this specie was recorded in Spain in 1993 (Muñoz and Soria, 1995). At the present time, it is wide spread in the Iberian Peninsula, even though it usually appears scattered on the affected forests. It causes premature leaves looses on oaks, contributing in the decay process caused by *la seca.*

- **Branches, twigs and trunk fungi**

- *Botryosphaeria stevensii (*Anamorph*: Diplodia mutila)*

In declining *Quercus* trees, cankers on branches caused by this fungus specie are commonly observed. Strips of necrotic inner bark on diseased branches are also rather frequent when this fungus is present. *Botryosphaeria stevensii* has been isolated from affected branches in several studies carried out in Spain (Sánchez et al., 2003). In fact, nowadays it is the most frequently isolated fungi from *Quercus* with decaying crowns in the Peninsula (Muñoz et al. 2003).

The infection kills branches and twigs and it consequently causes a important defoliation of the crown. Particularly, when attacking cork oaks, it causes wilting of the trees after cork is removed for industrial purposes (Luque and Girbal, 1989). Its occurrence and wide distribution around the Spanish oak forests point out its contribution to the *Quercus* decline in the country (Sánchez et al., 2003).

- *Coryneum* and *Cryptospora quercis (*Anamorph: *Cryptosporium conicum)*

These species do not cause big damages on the affected trees, but they are present really often on diseased oaks. They are associated with death twigs and branches. In Spain, *Cryptospora quercis* has been isolated from declining oaks, and four species of *Coryneum* have been also identified on decaying or death branches; *Coryneum depressum, Coryneum elevatum, Coryneum umbonatum* and *Coryneum megaspermum.*

- *Diatrypella quercina (*Anamorph: *Libertella faginea)*and *Hypoxylon mediterraneum (Biscogniauxia mediterranea)*

These fungi are defined as opportunist parasites attacking oaks in Spain. They are commonly growing on twigs and branches in different stages of alteration. They are usually associated with stress situations. *Hypoxylon mediterraneum* is particularly frequent attacking cork oaks, and it has been transmitted for many years by the tools used for the cork extraction (Oliva and Molinas, 1984). Its activity is quite slow, thus, the mycelium can be living on the trunk and the tree may not show any decline symptom until some years have passed.

- *Nectria coccinea (*Anamorph: *Cylindrocarpon faginatum)*

This fungus is more often found attacking other deciduous trees than attacking oaks. However, it is affecting *Quercus* sporadically, as an opportunistic parasite, causing big cankers on branches of declining trees. Thus, it contributes to the loss of the crown in trees affected by *la seca.*

- *Taphrina kruchii*

Especially common attacking holm oaks in the Iberian Peninsula, *Taphrina kruchii* is frequently present on different *Quercus* stands regardless whether the trees are declining or not. It causes damages on branches and twigs, speeding up the loss of the tree crown. It can be transmitted throughout wounds caused during the collection of acorns.

- Fungi belonging to the subdivision *Basidiomycotina*

Many fungi belonging to this subdivision have been found affecting oak trees in Spain. They are responsible for the rot of the trunks and their capacity of penetration through living tissues is very limited. In fact, they usually only penetrate easily through big cut sections provoked during pruning or through open wounds caused while uncorking. The tools used during these silvicultural interventions, contribute to the proliferation of the fungi, transmitting the spores from affected trees to the healthy ones.

Once the tree has been infected, these fungi species start degrading the wood on the trunks, but their damages cannot be observed on the tree crown during the first years of infection. Usually, there is a first stage where the fungi digest only the lignin, causing the so called white rot of the wood. By this time, the cellulose remains intact, but the support tissues have been destroyed. Then, the tree will be too weak for supporting a well formed crown, and some big branches will start breaking down, as well as the trunks can crack and the roots can be pulled off from the soil. According to Muñoz et al. (2003) the most frequent species found in Spain are: *Fomes fomentarius, Inonotus dryadeus, Ganoderma applanatum, Ganoderma lucidum, , Peniophora quercina, Phellinus robustus, Phellinus torulosus, Stereum hirsitum, Trichaptum biforme, Vuilleminia comedens.*

Fig .20 .Fruiting bodies of Fomes fomentarius. Source: Aranzadi 2008

- **Roots fungi**

- *Phytophthora cinnamomi*

The *Phytophthora* genus is probably the most studied biotic factor related to oak decline. Some authors defend that *Phytophthora cinnamoni* is the principal causal agent of *la seca* (Tainer et al., 2000; Tuset et al, 2002; Tuset et al., 2006; Gallego et al, 1999). Since 1991, this specie has been isolated in Spain from thin roots of decaying oaks. The genus includes more than 60 pathogenic species affecting different plants (Tuset, 2004; Sánchez et al., 2002; Gallego et al., 1999). They grow in the soils and they need the presence of living plant tissues and water in order to survive. In the first stages of infection, thin roots and the base of the trunk are affected on the trees. If the weather conditions are favorable for the good development of the fungi, they can grow on the bark of main roots and trunk.

Fig 21.. Sudden death of Q.ilex associated with root infection by Phytophthora cinnamomi in Spain.
Source:American Phytopathological Society, 2003

P. cinnamommi was actually introduced in Europe and distributed around the world, being probably original from Papua New Guinea islands (Brasier, 1996). In Spain, it has been isolated only from decrepit *Q.suber, Q.ilex* and *Q. rubra* (Tuset et al., 2002, Moreira et al., 2004). Soils with low fertility and low mineral nutrient levels, particularly phosphorus, seem to favour infection (Moreira et al., 2004). The development of the fungi is clearly linked to the availability of water on soils. Thus, according to Jung et al. (2000), there is a strong association between the presence of *Phytophthora cinnamomi*, interacting with prolonged drought periods, and rapid mortality and decline of cork and holm oaks. In other words, it usually interacts with drought and other site factors, and can lead to stress-related attacks by insects and other fungi (Brasier et al., 1993).

- *Armillaria*

Species belonging to this genus are able to live saprophytically in the ground or on the radical systems without causing severe damages. Only when certain unfavorable circumstances for the host tree occur, the fungi can cause important infections. In this case, they provoke ringing of roots and rot on the radical system in general. This can cause a significant dysfunction on the water and nutrients absorption and loss of stability of the main trunk and crown. Consequently, occurrence of slightly strong winds can easily cause the fall of the affected trees. When infecting young trees, the fungi develop rather fast, while their development on older trees is much slower.

It is not possible to observe any clear symptom on the aerial part of the tree before some years of infection have passed by. However, as the roots are being destroyed, the crown will finally show some visible damages. As mentioned before, this process can be speeded up by the presence of other damaging factors such as drought. In this case, the decay process can be so fast, than the trees experience sudden death in a very short period of time. These fungi species usually infect clusters of oak trees which are growing quite close to each other in a stand, since they can be transmitted through direct contact between their roots on the soil. In Spain, the most frequently found species are *A. mellea* and *A. tabescens*, especially in holm and cork oak forests affected by *la seca.*

- *Collybia fusipes*

This specie is not really common in the Spanish oak forest. However, it causes important damages when it is actually present. It rots the radical system of the infected trees. Its propagation takes place mainly through basidiospores, so the infection through direct contact of the roots growing in the ground, is not as important and it is in *Armillaria.*

Collybia fusipes has been detected in both, healthy and diseased *Quercus*. Its development can be very slow, but once more, it can be speeded up by drought periods or other big changes on water availability.

- VIRUSES

Nowadays, little is known about the presence, distribution and impact of viruses in natural forests. However, it is actually known that they cause damages in many stands, since they have been isolated and tested in different sites and experiments (Nienhaus & Castello, 1989). Some authors have even hypothesized that viruses and similar pathogens are one of the main causes of forest damage in Central Europe (Kandler, 1983).

Virus-infected woody plants may show changes in the bark or stem, including rough bark, gummosis and necrosis (Schneider, 1973). Oaks affected by *la seca,* showing some of these symptoms, might be infected with viruses. In fact, several viruses have been isolated from diseased oak trees around the world (Barnett, 1971; Kim and Fulton, 1973; Yarwood & Hecht-Poinar, 1970).

Viruses are considered as secondary factors contributing in the decline of the affected oaks, but never as the primary caused of the disease. Viruses interact with other abiotic and biotic factors, but unfortunately, there is not a lot of information about these interactions to date. They may predispose trees to other damaging factors, causing a faster decline than in case they were not there. Some stable viruses can spread without vectors while other viruses need always the presence of a particular vector to succeed, such as soilborne fungi, insects or nematodes.

- BACTERIA; *Brenneria quercinea*

Erwinia quercina, reclassified as *Brenneria quercinea* by Hauben et al. in 1998, was first described by Hildebrand and Schroth (1967) as the causal agent of the drippy nut disease of California live oaks. Later, it has been described and isolated from diseased oak trees in Europe. In Spain, it was first isolated in 1992 from *Q.ilex* (Biosca et al., 2003). Nowadays, it has been found in the Peninsula in bark cankers, drippy buds and drippy nuts in *Q.ilex* and *Q. pyrenaica* (Biosca et al., 2003) and in *Q. faginea* (López et al., 2004). Bark canker and drippy bud symptoms have been regularly observed in decaying oaks, but they were not described as caused by this bacterium until Biosca et al. isolations. During Biosca's study, no fungal pathogens were associated with any of these symptoms.

Regarding bacterial pathogens and their importance in oak forests, several bacterial species have been associated with the decline of *Quercus* species in different areas of the world (Scortichini et al., 1992; Barnard et al., 1998; Hildebrand and Schroth, 1967), although their pathogenicity have not been tested in every case. Oak trees where bacterial species have been found, always present bark cankers with exudates. These cankers can cause necrotic lesions extended to inner bark tissues, damaging the wood of trunk and branches. *Brenneria quercinea* has been also isolated from oozing and sticky acorns. The ooze can be observed at the base of the nut, as well as on the acorn cup once the nut has fallen down into the floor. Therefore, the bacterial infection is responsible for severe fruit drop, and consequently, the affected trees will produce fewer acorns (Biosca et al., 2003). Exudation from leaf buds is another symptom that has been recently associated with this bacterium (Biosca et al., 2003).

The isolations of *Brenneria quercinea* from decaying trees growing in many different regions of Spain, demonstrate that this specie is widely distributed through the oak forests around Spain. In every case, the studied trees presented several decaying symptoms such as longitudinal cankers and exudations from them and from buds and acorns. Thus, implication of this bacterial specie in the oak decline syndrome in Spain has been confirmed (López et al., 2004).

- ABIOTIC FACTORS

Although historically, most of the authors implied in the study of oak decline around the world, were primarily focused on biotic factors, there have been always some scientists defending abiotic factors as key agents involved in the decay process caused by *la seca* (Jacobs et al., 1993). In any case, the analysis and understanding of the abiotic factors affecting the diseased forests is clearly required. It is obvious that, in fact, interaction and combination of both, biotic and abiotic factors are responsible for the final status and evolution of a particular stand (Brasier, 1996; Coscuera et al., 2004; Thomas et al., 2002)

Among the implied abiotic factors we find factors related to climate (precipitation regimes, drought, extreme temperatures…), soil (lack or excess of nutrients, hydromorphic site conditions, compression of soils…) and chemicals (air or soil pollutants…). These factors determine the general characteristics of a certain site, which are always directly or indirectly influenced by human activities.

- CLIMATE & ENVIRONMENT

Climatic and environmental characteristics of the Spanish region are, per se, rather extreme, modelling a particular kind of ecosystems which need to develop and survive facing notable difficulties. Summer drought and a cold winter with frequent frosts are two critical periods characterizing the Mediterranean climate inside the continent. Some theories defend that the succession of several episodes of adverse climate in the region, during the last decades, has led to a situation where *Quercus* forests experience decaying processes and even death of the affected trees (Peñuelas et al., 2001). Thus, most of the authors who focused their works on abiotic factors, study the effects of climate on the functioning of the trees. Coscuera et al. (2004), support the idea that in Spain, the decline process in most of the affected forests by *la seca* has its origin in climatic factors.

Only a few authors, study other factors, such as air pollutants (Nienhaus et al. 1989; Bussoti et al. 1993), as the main cause of the oak decline. Thus, Bussoti et al. (1993) defended the high levels of air pollutants, in the surroundings of industrial areas, as the final implied factor in the disease.

Especially in the Mediterranean regions, it is clear than one of the most important climatic factors is an accumulated deficit of precipitation, together with an increase in temperatures, which creates critical situations regarding hydric stress. Therefore, drought is pointed out as one of the principle factors provoking the outset and early development of the decay on the trees (Coscuera et al., 2004). According to Thomas et al. (2002), summer drought and severe frost in mid-winter are presumed to be involved in the outbreak of oak decline. Actually, a high temporal synchrony in mortality tends to occur, particularly after drought years (e.g. 1990, 1992, 1994 2004 and 2005 were particularly critical years) (Sánchez and García, 2007).

Oak decline has been also related to the current climate change (Montoya et al, 2004; Sánchez and García, 2007; Herranz, J.L, 2004; Brasier, C.M., 1996). Special importance has been given to changes in distribution, frequency, and abundance of precipitations and the thermal extremes. For instance, Brasier et al. (2003) defend that predicted levels of global warming and climatic instability could favour some *Phytophthora* species such as *P.cinnamomi*, increasing their activity and spread in parts of Europe (and worldwide). Corresponding climatic stress on trees could also make hosts more susceptible to *Phytophthora* species. This example points out the importance of the interaction between biotic and abiotic factors, since probably any of them acting alone, could cause important damages.

In general, problematic site conditions regarding soil, such as compression, lack of nutrients or presence of pollutants, will also lead into a devitalization of the trees which will be more susceptible against other damaging factors. For example, some studies show that soils with low fertility and low mineral nutrient levels seem to favour infection by *Phytophthora cinnamomi* (Moreira et al., 2004).

- SILVICULTURAL MISMANAGEMENT

It is worth mentioning that all the oak forests experimenting decline due to *la seca* in Spain and, probably around the world, have been influenced in some extend by human activities. Management of a certain forest always has an impact on the characteristics, development and evolution of these, in origin, natural systems. In fact, proper management of wild live is the main sanitary tool in a natural system (Montoya et al., 2004). In the last few decades, when *la seca* seems to have caused bigger damages, there have been important changes regarding management of the Spanish oak forests (Montoya and Mesón, 2004). Thus, in several occasions, inadequate management of oak forests has been referred as a predisposing factor of decline (Sánchez and García, 2007; del Pozo, 2004; Montoya and Mesón, 2004).

Human activity has caused the destruction of part of the Mediterranean forests in order to create agronomical and grazing lands, while the rest of the forest was partly transformed into low forests for the production of firewood and charcoal. Therefore, some of the original forests disappeared and the structure, functioning and species composition of some others were altered. According to Thomas et al. (2002), outbreak of oak decline can be attributed to inappropriate silvicultural management, which had led to the cultivation of *Quercus* species at sites that are unfavourable to these species. Besides, in the middle of the 20th century, the generalization of the use of fossil fuels and abandonment of rural areas, turn out in putting aside the traditional exploitations of the low forests of *Quercus.* These neglected oak forests are more affected by *la seca*, since the trees will age faster than they would in a properly managed forest (Coscuera et al., 2004).

Actually, one of the most essential issues all around Europe is land abandonment, which seems to be an important factor of decline. Among other direct consequences, fire hazard is associated with land abandonment, since it increases the available fuel in a particular site (Piazzeta, 2007). Fortunately, most of the species that form a part of the *dehesas* can survive after a fire and some of them can even make profit from these fires. However, fires become a problem for the equilibrium of the forest when they take place in the wrong location, frequency or temperatures. Man should manage the system to try to avoid possible fires and to control shrubs invasion after them, but this is not always the case.

As mentioned before, oak forests forming *dehesas,* have been managed in order to obtain multiple products and benefits. Year after year, the exploitation of these stands has been intensified in some degree, in response to new socioeconomic circumstances. This fact has turned out in many cases in an inappropriate use of the forest, causing damages over the system and in particular over the natural regeneration of the tree layer.

Dehesas where Iberian pigs or other pigs are feeding directly on the acorns from the trees, usually lose stability and suffer damages when the carrying capacity is exceed or if the grazing time is too prolonged. This problem has become more common during last years, because it is more frequent to create closed areas with fences in order to keep the animals gaining weight in a particular portion of the *dehesa*. Consequently, they often cause problems such as compression of the soil, concentration of solid and liquid residues due to excrements, dust accumulation over the leaves and debarking of the base of trunks. These problems will result in a loss of vigour by the trees growing in that particular *dehesa* and in a decrease of natural regeneration due to lack of viable seeds on the site.

In those other *dehesas* which are dedicated to extensive livestock, besides pigs, there is also often a problem when overtaking carrying capacity of the site. In the last years, the European Union gave important subventions to farmers, especially for grazing cattle (Del Pozo, 2004). This made possible that the carrying capacities of many sites were overtaken. They could supplement the feeding of the animals with artificial fodder and retain the cattle on the fields all year long. This causes compression of soils, problems of natural regeneration, contamination of soils for excessive accumulation of organic manure and numerous mechanic damages on trees. As direct consequences, trees will decrease their growth rates, there will be open wounds susceptible to be attacked by fungi, insects or other biotic factors, and the stand will experience a fast ageing due to lack of regeneration and death of new suckers and sprouts. Once again, these problems will have a negative impact on the oak decline process caused by *la seca*.

Management of cork oak stands is a special case. Cork extraction is a difficult process where sever damages can be caused to the trees if it is improperly done. It is made by hand by experienced experts and it can be particularly dangerous when the trees have experienced any kind of stress (a long period of drought, attacks by

Coroebus undatus, defoliation by leaf feeders, devitalization by fungi infection…etc.). This means that cork extraction is more difficult in affected stands by *la seca.* And what is more, cork extraction will represent one stress factor more for the trees.

During other silvicultural practices, such as pruning or brushing treatments, damages on the trees can also be caused. Wounds reduce the general healthiness of the trees and make them more susceptible against pathogenic insects and /or fungi. Transmission of these pathogens is usually facilitated by the used tool for these management practices.

The last human influence which has to be mentioned in this section is in a higher level. It refers to the current climate change caused, at least partially, by human activity. Human are responsible for air pollution, acid rain, green house effect, water pollution, etc. which directly or indirectly will affect oak decline and its evolution.

- DAMAGES ASSESSMENT

Since the first patent processes of decay that were registered in Spain in the middle of the 80's, several surveys at regional and national level have been performed with the aim of knowing the extension and the evolution of the damages as well as defining the different parameters that can play an important role in the process.

The year 1988 represents the starting point for the damages surveys at a national level. The noticeable damages detected in cork oaks in the south and southwest of the Peninsula were object to study from 1990 with annual periodicity, during three years. The apparently aggravation and spreading of these damages to holm oak stands, provoked the elaboration and practice of a pilot program in 1991 for the analysis in depth of the situation regarding this species and all the implied symptoms and factors.

The new intensity of the damages that has been reached in the recent years made that, in 2003, a new pilot program focused on an area where severe and recurrent damages have been reported. This survey aims to develop a sampling methodology which can be applied at every *Quercus* stand in the Mediterranean region. Besides, it will provide, continuously and periodically, with homogeneous information about the status and evaluation of the affected areas by *la seca*. It is worth mentioning that, considering the complexity of the symptoms and patterns of the disease, it is extremely difficult to homologate the criteria when characterizing the affected areas and the causes and elements contributing to the process.

At the same time as these surveys have been carried out, Forest Health Inventories within the European Level I Network, which was set up in 1987 for the assessment of damages in forests, have been annually carried out. Thanks to the information available from these Forest Health Inventories, a dynamic vision of the Spanish forests is available today, and affected areas by *la seca* are easily detected.

Different sampling methodologies, in terms of intensity and evaluation, are used according to the gravity of the attacks at each particular Autonomous Community. Particularly, in Andalusia Community they have developed a model methodology deserving of being admired and congratulated (Sánchez, 2004). In general terms, the elaboration of the Forest Health Inventories is based on a systematic 16 km wide grid for monitoring, in which vertexes are installed the sampling sites, including each of them 24 trees whose health will be analysed annually. The results will be grouped in five different classes or vitality indexes, ranking from “0” (totally healthy) to “4” (death). Class “1” means slightly damaged trees, class “2” moderately damaged and class “3” severely damaged.

The factors which are always analysed are: altitude, stand characteristics, orography, slope, orientation, soil type, flooding, practices or exploitations carried out, location of damages attending to different vegetation layers, present symptoms and extension of their damages, domination of each symptom on the stand and distribution of damages in surface, among others.

In Spain, the European Level I Network includes 620 plots distributed around the whole country, which means a total of about

15.000 trees. Among them, more than 3000 are holm oak trees and almost 400 are cork oak trees.

Of course it is difficult to assess the damages from a complex disease, but we have seen how all these programs and studies provide with a lot of valuable information which allow us to understand better the importance of the damages caused by *la seca* and help us in the interpretation of the evolution of the decline. Each year, more and more standardized and detailed programs are elaborated for improving the collected data and the interpretation of this important information. However, interpretation of damages in this kind of forests are always relative, since a lot of political, social and economical factors are implied.

- HOW HUMANS CAN IMPROVE THE SITUATION

As known, humans can always influence over the dynamics of natural ecosystems. As we have seen in the previous sections, *la seca* is not an easy process to be controlled by humans due to the complexity of the etiology of the disease. However, all around the world some ideas about the adequate treatment of oak stands have been presented in order to prevent the outbreak of the disease or to mitigate the effects of it over the affected regions.

In Spain, especially for different public institutions of forest management and research, *la seca* is nowadays a matter with priority over many other environmental issues. Maybe the definitive solution to the syndrome (if there is such a solution), is still far of being understood by humans, and of course, it will require even a bigger effort in terms of people and time, but the first steps have been already taken.

In light of all the knowledge that has been gathered from the eighties till today about *la seca* in Spain, it has been possible to elaborate some silvicultural recommendations for the forest managers and the research fields are still open and active.

- STRATEGIES OF MANAGEMENT
  - PREVENTIVE TREATMENTS

Oak decline can be controlled, or at least reduced or delayed, if a proper silvicultural management is carried out before the first outbreak had come (Montoya et al., 2004). Preventive treatments are attempts to reduce or avoid some stress agents or situations which could entail the outset of the oak decline process.

All silvicultural practices aimed at improving the health of the trees, will reduce the potential damage of the decay caused by *la seca.* The more resistant and better adapted to the environment trees, the less damage registered (Coscuera et al., 2004).

The most common recommendation for prevention against *la seca* is the creation of new and healthy stands. Firstly, it is necessary to facilitate and improve natural regeneration of the stands, but artificial reforestation can be also applied if required (Montoya et al., 2004). The progressive substitution of decrepit trees for young seedlings in a stand also prevents against the spreading of the disease towards other trees or near stands. Burning or extraction of death trees is highly recommended (Piazzeta, 2007).

Natural regeneration must be then favored against artificial regeneration, since the procedures applied are more ecological, cheaper and the created stands will be more stable, and long-lived (Montoya et al., 2004). The posterior control and monitoring of the development and evolution of the stands is crucial for both, natural and artificial regeneration practices. When artificial regeneration is carried out, it is of vital importance to select the proper seeds or seedling in order to succeed. Provenance and healthiness of the new individuals must be taken into account to prevent failures of the reforestation.

Besides, every level of the system must be managed and controlled in some extend. The decay of the oak forests implies not only death of the tree layer, but also a general disequilibrium of the ecosystem, which can include the understory species, crops, grasses, animals…etc. Selection of the right elements accompanying the tree layer for the creation of a robust, stable and resistant system will prevent the devitalization of the stands.

Fig . 22. Natural pasture growing in a dehesa in Central Spain. By Clara G.A.

Regarding *dehesas* where pigs feeding on acorns are raised, in order to avoid damages caused by overtaking the carrying capacity of the site, it is recommended in first place to create systems where the animals can occupy wider areas throughout the year. Creation of stables, where they can spend some time, and where the manure and urine will be properly treated is another option. Timing is also a crucial factor in this complex system. To control and reduce the proliferation of acorn feeders insects, the grazing should be carried out during November and December, thus, the nuts will be consumed in a short period after they have fallen down from the trees (Del Pozo, 2004).

Use of adequate carrying capacity in *dehesas* where other livestock is raised, is also of crucial importance. Selection of the appropriate artificial supplements for the cattle or other animals is essential too, as well as the areas where these supplementations have place (they must be alternated in space). Fencing of too small areas during long periods of time must be avoided as well.

In order to avoid the disease to be transmitted from affected areas to healthy stands, appropriate cleaning of tools used during silvicultural treatments must be done. Especially tools used for cork extraction or pruning have a high risk of transmitting fungi, insects or virus from tree to tree. Some machines and tools used for soil treatments can also transmit pathogens through direct contact with the root system of the trees.

Genetic improvement of the plants present in a particular *dehesa* or oak forest has been also mentioned by some authors (Tapias et al., 2006). In particular, the crops combined with the tree layer in some *dehesas* could be genetically selected according to the circumstances, trying to create a more resistant system against *la seca*. Also, possibilities of use of genetic variability of resistance or tolerance of trees to the pathogen *P. cinnamomi* have been considered (Tapias et al., 2006).

Introduction of exotic species must be avoided, since this practice can entail the introduction of new pathogenic agents, especially insect pests or fungi. Their attacks might be quite difficult to control because of lack of natural enemies on the sites and lack of knowledge about the development of these new agents in such a new environment.

▪ TREATMENTS FOR MITIGATION

The complex etiology of *la seca,* makes difficult to outline common mitigation treatments to alleviate or stop the effects of the ongoing decline. Considering the multiple factors implied on the disease and the remarkable variability of environmental and historical conditions of the different stands, it is complicated to act in a way which will be effective against all, or at least several of these factors at dissimilar sites. That is why, many different treatments have been presented by several collectives, and some of them have been already applied on the field. Most of them are focused on one particular involved factor, depending on the authors' opinion and the characteristics and situation of the particular stand being treated.

In general, all proposals point out the requirement of applying good management practices and avoidance of abandonment of the affected stands. Thus, the first required step for applying all these mitigating treatments, as well as preventive ones, is avoiding abandonment of oak stands and maintaining the traditional exploitation practices. This means that a change in mentality for many foresters and owners is needed. Therefore, there is also a scope for action at the policy level, as neither abandonment nor overuse is compatible with sustainability of Spanish cork and holm oak stands.

Mitigation practices try to transform the decaying stands in more healthy stands in order to eradicate the infections. Thus, management of affected forests tends to create more vigorous stands, with younger and healthy oaks, and compatible with traditional practices. For this purpose, replacement of affected trees with healthy seedlings can be performed and this will decrease the damages caused by *la seca*, eliminating some of the pathogens that where present in the stand and increasing the proportion of healthy individuals in the formation. When afforestations are part of the plan, mycorrhized seedlings have been used in some cases.

In oak forest where animals graze, good planning of the grazing activities is crucial. Recommendations lead to avoid grazing in the end of summer and beginning of autumn, mainly for decreasing damages caused by the animals on the natural regeneration of the forest. Deferred grazing plans are more suitable to be sustainable when oak decline is already taking place (Sánchez and García, 2007).

In affected cork oak stands, it is recommended to avoid harvesting in years of drought or of high pest incidence. In this way, the infected trees will likely recover some vigour instead of getting weaker due to the effects of the extraction, which represents, after all, another stress factor for the tree. For preventing a fast spreading of the disease inside an infected stand, use of uninfected tools in cork extraction as well as in other silvicultural activities, such as pruning or wood collection, is highly recommended too.

Numerous pest control practices have been applied in the Spanish oak forests where insects have been considered an important factor involved in the decay processes. The need of applying chemical treatments has been only justified when the population of a certain species rockets, aiming to prevent damages that they would cause on the trees due to total or recurrent defoliations during several years

(Sierra et al., 2004).The treatments are planned in order to maintain the populations within the threshold of tolerable damages. Previously, it is required to evaluate if the biological control by parasitoids and predators would be insufficient for the natural control of the treated populations. Also several treatments for mitigating the damages caused by fungi infections or for avoiding the fungi to continue their spreading have been applied to slow down the decay produced by *la seca.* A number of these experiments did not have so good results as they were expected (Sánchez, 2004).

As it has been mentioned before, some authors defend that climate change is affecting negatively in this situation (Herranz, J.L, 2004; Brasier, C.M., 1996). That would mean that every silvicultural treatment carried out in order to mitigate the effects of climate change over the *Quercus* forest ecosystems, will contribute to slow down the oak decline process. Thus, in the near future it would be very interesting to improve the existing techniques for mitigation and adaptation to climate change. Minimizing the impact of these climatic changes and increasing the resilience of the *Quercus* ecosystem, these human activities could reduce the spreading and strength of the oak decline disease.

- THE ROLE OF RESEARCHING

It seems to be obvious that one indispensable need for successfully dealing with *la seca* is to keep on researching. Many research fields have been open during the last almost 30 years. A lot of investigations have been focused on the search of a unique and final factor responsible for the disease. Thus, we have seen that many authors still defend one single factor as the causing agent of the disease. However, we already mentioned that probably the disease is rather caused by a synergy of damaging and stress factors, which is very heterogeneous depending on the considered site, environment and situation. Due to all these different interpretations, an impressive number of investigations and studies have taken place, and they have revealed a lot of characteristics about the decline process of the diseased trees. Thus, we have gathered a lot of information obtained from really different collectives and perspectives, which in fact represents the acquisition of an important knowledge about such a complex phenomenon.

Some research fields have been deeply studied and understood, while others have only been slightly explored. In any case, most of them are still active and open, and new fields might be proposed in the near future. Even knowing that we are in urgent need of acting on the field in order to prevent and mitigate the effects of oak decline (Montoya and Mesón, 2004), researching must continue for farther increase of the knowledge about the causes of the phenomenon and to be able to find better and more general solutions to the problem.

Nowadays, research fields cover mainly all the factors implied in the disease and the role of human in the evolution of the ongoing decline. Lately, there is a tendency towards the study of interactions among different factors, which are crucial for the better understanding of the disease. We can mention in general terms, some of the current research fields: study of particular biotic factors such as *Phytophthora cinnamomi* among the fungi, *Brenneria quercinea* as bacteria, virus or several insect pests, interaction among different biotic and abiotic factors, effects of environmental factors on the process such as site conditions, influence and consequences of climate change, techniques for prevention and mitigation, genetic improvements…

Clearly, it is of extreme importance that the authorities of the Administration of the Estate and of the Autonomous Communities continue supporting economically this kind of studies to move on in the understanding and control of the disease.

• CONCLUSIONS

After almost 30 years of studies and research about oak decline, a lot of useful information have been gathered and shared all around the world. The complexity of the disease is the first reason why it has been so complicated to deal with the decline process suffered by the affected forests. Cases of *seca* cannot be explained by just one single factor, since it is always a combination of them which actually cause the decline on the stands.

Thus, instead of considering single factors as responsible for the outbreaks of the disease, we should study and better understand the interactions among the different stress factors. So, it is clear than research must go on for improving the situation and making easier the search and definition of the right silvicultural practices for facing the disease and its consequences.

Every case seems to be particularly different, but we know already a lot about the implied factors and now we need to act more. We do know that, at least in Spain, the spreading of the disease is still increasing and the damages are more and more important year after year. Our mismanagement is just making worst the situation, and in fact, we know that we could do a lot to improve the situation just applying some good silvicultural practices.

During the last decade, many recommendations and practices for mitigating the consequences of the decline process and for preventing the spreading of the disease have been developed. Application of these techniques might lead us to a better situation. However, it is concern from different collectives, the first thing which is required for the success of these treatments. Then, support from governments is crucial in these cases. Particularly in Spain, if a *Quercus* forest turns out to be not productive anymore, the owners and workers will not apply any treatment for saving the forest unless they can be sure that these practices would actually work in a short term and they will be able to obtain benefits from their forests again. After all, the forest was their source of money for living so it is understandable that they abandon them if they do not have benefits from them and they do not receive any aim from national or international organizations.

Oak decline entails important economical losses in Spain, but we have to keep in mind that it is also a matter of biological losses and all the consequences that these losses can caused. Maybe in other countries is currently not such an important problem, but especially under these frame of climate change, we should be aware of the possible spreading of the disease or possible changes on the development and evolution of the decline all around the world. We should not be pessimistic about the future, we have a lot of information about the disease and a lot of possibilities to act against it. After all, we are one of the main implied factors, so whether or not we want to act against it is, at least in some extent, in our hands.

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• APPENDIX

The map below represents all the provinces of Spain and Portugal:

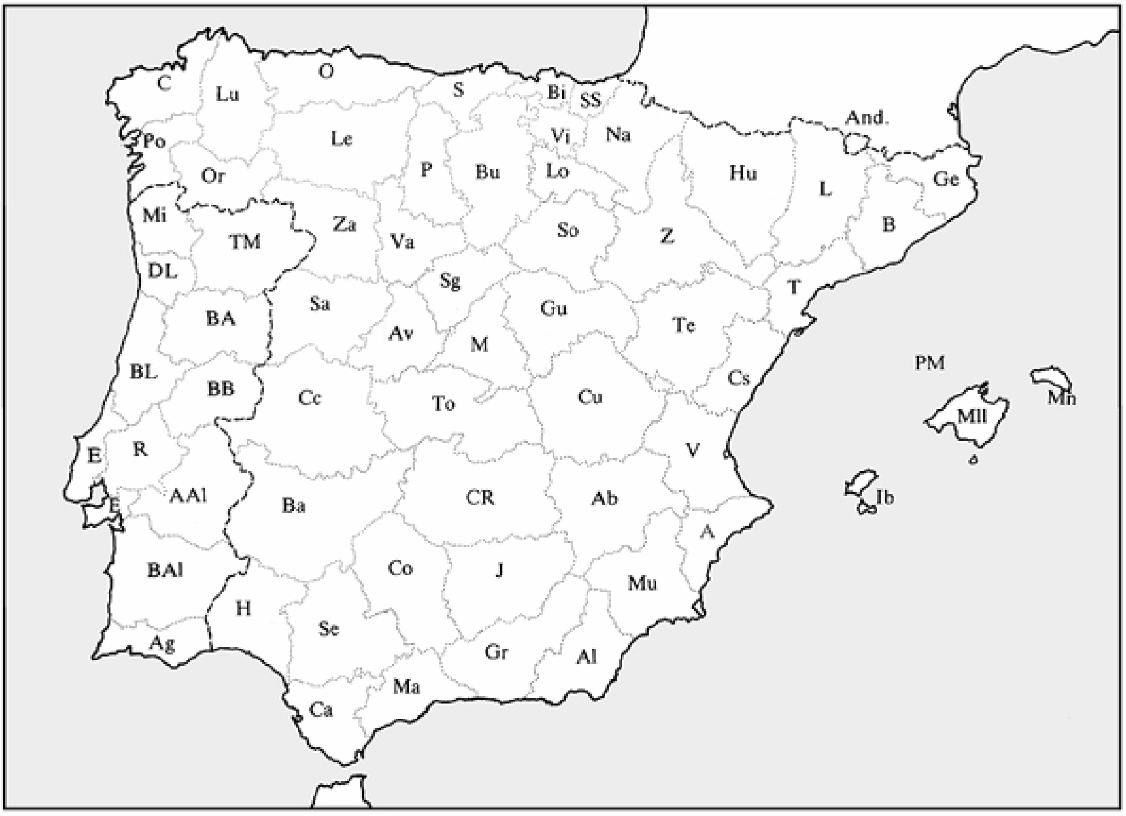

Fig. . Provinces of Spain and Portugal. Sorce: Flora ibérica (2008)

Next table clarifies the abbreviations used for the Spanish provinces in the previous map:

Table . Abreviations for provinces of Spain. Source: Flora ibérica (2008):

Spain					
A	Alicante	**Gu**	Guadalajara	**Mn**	Menorca
Ab	Albacete	**H**	Huelva	**Ib**	Ibiza
Al	Almería	**Hu**	Huesca	**Po**	Pontevedra

Av	Ávila	**J**	Jaén	**S**	Cantabria (Santander)
B	Barcelona	**L**	Lérida (Lleida)	**Sa**	Salamanca
Ba	Badajoz	**Le**	León	**Se**	Sevilla
Bi	Vizcaya	**Lo**	La Rioja (Logroño)	**Sg**	Segovia
Bu	Burgos	**Lu**	Lugo	**So**	Soria
C	La Coruña (A Coruña)	**M**	Madrid	**SS**	Guipúzcoa
Ca	Cádiz	**Ma**	Málaga	**T**	Tarragona
Cc	Cáceres	**Mu**	Murcia	**Te**	Teruel
Co	Córdoba	**Na**	Navarra	**To**	Toledo
CR	Ciudad Real	**O**	Asturias (Oviedo)	**V**	Valencia
Cs	Castellón	**Or**	Orense (Ourense)	**Va**	Valladolid
Cu	Cuenca	**P**	Palencia	**Vi**	Álava
Ge	Gerona (Girona)	**PM**	Islas Baleares	**Z**	Zaragoza
Gr	Granada	**Mll**	Mallorca	**Za**	Zamora

Spain is divided into 17 Autonomous communities as represented in the map below:

Fig. . Autonomous communities of Spain. Source: Wikipedia 2008.

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