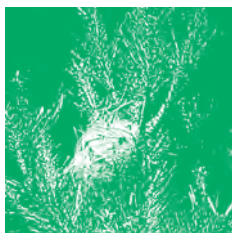




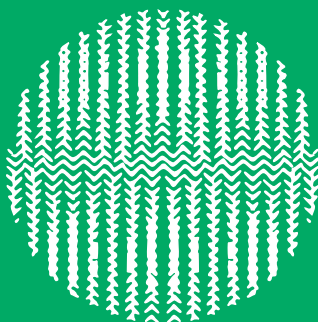
ENTOMOLOGICAL RESEARCH IN MEDITERRANEAN FOREST ECOSYSTEMS



Editors

**F. LIEUTIER,
D. GHAIIOULE**

SCIENCE UPDATE



INRA
EDITIONS

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Preface

Human presence in the Mediterranean basin is very ancient and has exploited nature for a long time. Indeed, many old conquering civilizations in Asia Minor, Europe and North Africa (Mesopotamian, Egyptian, Greek, Roman, Carthaginian, Arabian) developed in the Mediterranean crucible, and the human pressure on nature has consequently always been intense on the ridges of the Mediterranean Sea. The human action has concerned especially the forests (fire, wood collect, deforestation, pasture, cultivation and, more recently, tourism). As a result, direct effects on the forests and indirect effects on soils and micro-climates have led to a considerable decrease of the forested areas over the centuries, as well as to a degradation of the sanitary situation of the stands. A policy of preservation or reforestation has been developed during the 20th century in most regions around the Mediterranean Sea but the wooded areas are still not sufficient. Moreover, the original specific composition of the forests has considerably changed over the centuries. In many regions, because of irreversible perturbations, especially of the soil, the original climax tree species that were in equilibrium with the primitive soil and the climate have not been able to recover and are unable to be maintained if they are reintroduced. In these regions, the recent natural successions have thus led to pseudo-climax stands of various pine species, that have replaced the original climax stands of cedar and sclerophyl oak species. In addition, on many occasions, reforestations have been extensive monospecific plantations of exotic tree species, such as *Eucalyptus*, *Acacia* or pines. Exotic pests, insects and fungi, have followed their hosts in the novel environments.

The intensive and long term human pressures, combined with deep modifications in the components of forest ecosystems (concerning both the trees and the insects / fungi), have thus resulted in the present unbalanced situation of the Mediterranean forest ecosystems. This situation, exacerbated during the last decades by long range climatic modifications, is responsible for the today alarming sanitary conditions of the Mediterranean forest on a large scale. No region is spared and most tree species are concerned, be they introduced, pseudo-climax or primitive. *Eucalyptus* plantations, pine stands, primitive cork-oak and cedar forests all exhibit living trees that are prey to insects and fungi, often extending over large dieback areas.

The Mediterranean ecosystems are also characterized by a high diversity of living organisms (belonging to many different groups) when compared to those of Mid-Atlantic and continental Europe, although their biomass is not very high because of the dry summer period. For example, 11 pine, 10 fir and approximately 12 oak indigenous species live in the narrow Mediterranean area, while respectively 7, 2 and approximately 7 species are counted all over the rest of Europe. This high specific diversity in both animal and plants results from greatly diversified micro-environmental conditions which offer a large number of ecological niches to the living organisms, the whole contributing to high ecosystem diversity. The Mediterranean areas are thus highly favourable places to study biocenotics and plant-animal evolutionary relationships. They also provide numerous models for closely related situations, which is very useful for comparisons and building general rules. Owing to the intense human pressure, preservation of the biodiversity in these areas is also a crucial problem on all scales, from genes to landscapes, and studies must take this aspect into account.

This book focuses on the entomological aspects of the Mediterranean forest ecosystems. It is the proceedings of the first international symposium "MEDINSECT", which was organized jointly by the Institut National de la Recherche Agronomique (INRA, France), the Centre National de la Recherche Forestière (Rabat, Morocco) and the University of

Orléans (France) and held in Rabat from 6 to 11 May 2002, on the “Entomological Research in Mediterranean Forest Ecosystems”, completed by additional syntheses. Considering the importance of the phytosanitary problems, the necessities of biodiversity preservation and the potentialities for basic and applied scientific studies, it is not surprising that entomological studies related to these ecosystems are highly diversified. However, until very recently, many were carried out by isolated scientists, and often without concert. This scientific community was often ignorant of the number of its members and the names of the laboratories concerned. Rarely, and only recently, have some problems been considered on the scale of the whole Mediterranean basin, although the large number of different situations, even for the same insect species, makes it a favourable situation from which to draw general conclusions with large scientific hearing. These dispersed entomological research activities have resulted in an under-exploitation of the scientific possibilities of the Mediterranean basin, as well as in no solution to several phytosanitary problems and in large deficiencies in insect and, more generally, biodiversity preservation. This realisation was the main reason for holding the MEDINSECT symposium: an important and urgent need for all entomologists concerned with Mediterranean forest ecosystems to exchange directly their experiences and make their work known to their counterparts. It is also hoped that such plenary meetings can lead, in a step further, to building common research programs on forest entomology on the Mediterranean scale in order to bring concerted solutions to problems at the level of the Mediterranean basin.

Taking this idea into consideration, the topics presented at the symposium and in the book largely exceed the Mediterranean basin itself. Several types of Mediterranean ecosystems existing in the world are taken into account to allow fruitful comparisons to be made. In addition to the north and the south rims of the Mediterranean Sea which already offer contrasted situations, New Zealand, South African, and North and Central American situations are examined. A general overview of the entomological situation and research topics in the forests of these different regions is first made, then detailed examples of research carried out in these areas are presented.

The book is not a complete presentation of all entomological research and not even of all entomological problems existing in the forested Mediterranean areas, but it gives an idea of their diversity. Taking into account the above considerations, it is not surprising that most research on Mediterranean forest insects focuses on pest problems. For a long time, a number of studies have dealt for a long time with analyses of the life cycles and general biology of the pests, an indispensable approach to obtain basic data necessary for phytosanitary prevention and protection. Control methods, mainly biotic, have also been tested on several insect species in various situations. However, several studies now tend to develop more experimental and synthetic approaches. Relations with host trees are considered at the population level for both the insect species and their hosts. Other studies analyze inter- and multi-specific relationships and take into account the ecosystem by considering, not only the populations of pests and trees, but also the functional groups of organisms. The necessity of biodiversity preservation on all scales is also present.

François Lieutier
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Part 1

**Insects in the Mediterranean
Forest Ecosystems**

Overview of entomological research concerning the forest ecosystems of the northern rim of the Mediterranean Sea

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Summary

An overview of data concerning forest areas in the 16 countries along the northern rim of the Mediterranean Sea is given and indicators of insect damage are provided, whenever available. A database has been prepared by retrieving references from the CAB database for the period 1972-2001, for each main host plant and insect pest. Pines are the most intensively studied trees, particularly because they are vulnerable to two very important pests, the pine processionary moth and the pine bast scale. Among the insects that attack broadleaved trees, *Lymantria dispar* is by far the most often studied. Information taken from general sources and handbooks concerning forest insects in each country is presented and compared. The activities of international research groups and networks focused on Mediterranean forest entomology are summed up. Present research trends in this field are discussed and the objectives of ongoing projects at the European as well as the national level are presented. Finally, suggestions about future work in this field are given.

Résumé

Aperçu sur les recherches entomologiques dans les écosystèmes forestiers de la rive septentrionale de la Méditerranée

La superficie forestière dans les 16 pays du pourtour septentrional de la Méditerranée a été prise en compte et toutes les informations disponibles sur les dégâts des insectes ravageurs ont été analysées. Une base des données a été construite à partir des articles publiés

pendant la période 1972-2001 et présents dans la base de donnée des CAB. La recherche a été ciblée sur les plantes-hôtes et les ravageurs. Les pins sont les espèces les plus étudiées, en raison de la grande importance de certains ravageurs, notamment la processionnaire du pin et la cochenille du pin maritime. Parmi les insectes des feuillus, *Lymantria dispar* est l'insecte le plus étudié. Les sources générales d'information sur les insectes forestiers sont présentées pour chaque pays et comparées, en ce qui concerne soit les ouvrages à caractère général soit les manuels pratiques. Les activités des groupes de travail internationaux en entomologie forestière méditerranéenne sont présentées. L'orientation actuelle des recherches dans ce domaine est discutée et des suggestions sont finalement données.

Forest ecosystems and insect pests

The geographic area covered by this study includes 16 countries along the northern rim of the Mediterranean Sea. They are, from west to east: Portugal, Spain, France, Italy, Slovenia, Croatia, Yugoslavia (Serbia and Montenegro), Albania, Macedonia, Greece, Bulgaria, Turkey, Cyprus, Syria, Lebanon and Israel. The total forest area of this region is 69.4×10^6 ha, about 2/3 of which grow in a Mediterranean-type climate and the other mainly in an alpine-type climate. The forest is generally evenly distributed at upper latitudes/elevations, whereas it becomes less abundant in the south (percentage of forest cover on overall land area: 23.9%, with a minimum of 2.5% in Syria and a maximum of 55% in Slovenia). During the period 1990-2000, the yearly rate of increase of forest area was 0.45%, whereas an increase of only 0.08% was observed in Europe and the overall world rate was negative (-0.24%) (FAO, 2001).

The forest stands are mostly composed of native tree species, either broadleaves (*Quercus*, *Castanea* and several other genera, covering about 65% of total forest area) or conifers (*Pinus*, *Abies*, *Cedrus*, *Cupressus*, *Juniperus*, covering about 25% of total forest area). However, extensive plantations have been established with native as well as exotic tree species on about 10% of total forest area (e.g. *Pinus radiata*, *Eucalyptus*, *Populus*). Logging has declined over the last decades for several reasons and forest area is now expanding. However, in some parts of the region, uncontrolled forest fires and grazing may still represent major disruptive factors.

Pests and diseases are also recognized as being important limiting factors for the growth and survival of forest stands. The region has been hit by major world-wide epidemics (e.g. Dutch elm disease) as well as other epidemics common to the Mediterranean region, such as pine bast scale on *Pinus pinaster*, cypress bark canker and chestnut blight disease.

Unfortunately, reliable estimates of the insect pest impact on forest ecosystems at the Mediterranean level are not available. National and regional reports are available instead (e.g. France: Annual Report on Forest Health, "La Santé des Forêts"), but it appears difficult to obtain comparable data from surveys conducted with different methods and aims. Permanent monitoring networks that detect tree mortality, defoliation and discoloration, often do not correlate the damage with the presence of insects or pathogens. The main problem here is the high number of insect/fungus species and the difficulty in training and operating a sufficient number of specialised personnel.

For these reasons, it appears reasonable to assume that the importance of insect pests in the Mediterranean region is reflected by the number of publications available for each insect species/group or for a given host plant. Additional information can be obtained by

handbooks and textbooks published in different countries and by the activity of work groups devoted to dealing with specific problems.

Research papers indexed in the database

The CAB database was questioned for the period 1972–2001, using two search keys. The first search key, "tree species' name and insect and Mediterranean", retrieved tree species. The second, "insect species' name and Mediterranean", retrieved insect species. On the basis of these keys, all of the papers matching the request in any of the countries included in the Mediterranean region were retrieved from the database and imported by Reference Manager 9.5 software (ISI ResearchSoft, 1998). References were manually checked and duplicates were removed as well as papers not relevant to the objectives of the review. The databases were then analysed by retrieving references matching specific requests.

As for papers dealing with forest insects excluded by this analysis, i.e. papers published before 1972 or not indexed in the CAB database, a specific analysis was done using the pine processionary moth, *Thaumetopoea pityocampa*, as an example, and a total of 348 papers were indexed. A total of 45 of these papers had been published before 1972 and about 50 papers, mostly of minor interest, were not indexed. The survey therefore appears to include most of the published material on this insect pest in the Mediterranean countries.

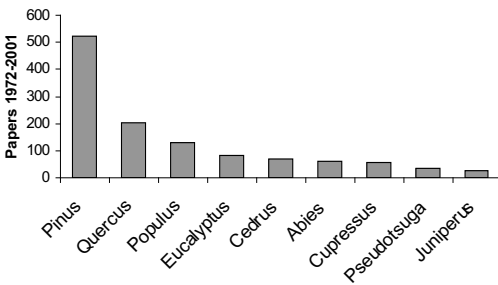


Fig. 1. Number of papers published during the period 1972-2001 on forest insects of the northern rim of the Mediterranean Sea, according to the genus of the host plants.

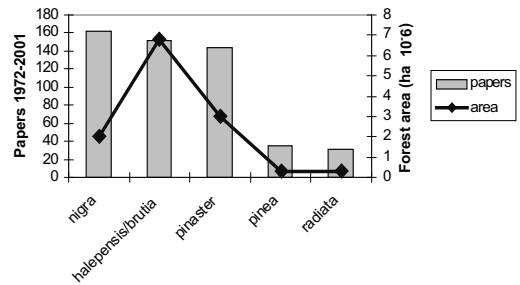


Fig. 2. Number of papers published during the period 1972-2001 on forest insects by *Pinus* species, and forest area covered by each pine along the northern rim of the Mediterranean Sea (sources: CAB International, 2000; Barbéro *et al.*, 1998).

In spite of the smaller area covered as compared with other tree genera (e.g. *Quercus*), pines are by far the most intensively studied species (fig. 1). This probably comes from the fact that pines are generally used in forestry planting, especially in dry zones where the forest cover may be extremely important for both soil protection and landscape value. Taking a closer look at the genus (fig. 2), it appears that some species have been given more attention than others by forest entomologists (e.g. *P. nigra* and *P. pinaster*), independently of their occurrence in the area. This can be explained either by the economic importance of the host tree or by the presence of insect species which are particularly aggressive, such as *T. pityocampa* for *P. nigra* and *M. feytaudi* for *P. pinaster*. In fact, these two groups of forest insects are the most thoroughly studied among those related to conifer tree species (fig. 3). Defoliating insects appear to be the most highly studied species among insects of broadleaved trees (fig. 4), whereas the gypsy moth (*Lymantria dispar*) is by far the most highly studied species, in general. However, phloem and wood boring insects have also received a great deal

of attention, especially when they attack trees of economic importance. Such was the case for the *Phoracanta* longhorn beetle and non-native eucalyptus trees.

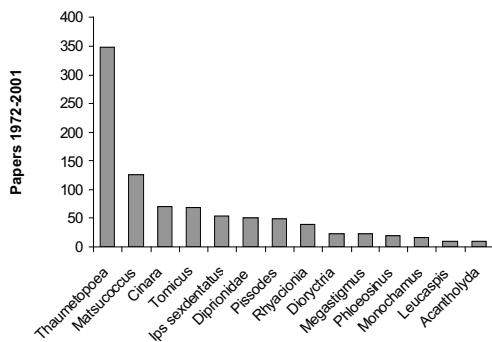


Fig. 3. Number of papers published during the period 1972-2001 on each main forest insect genus related to conifer tree species.

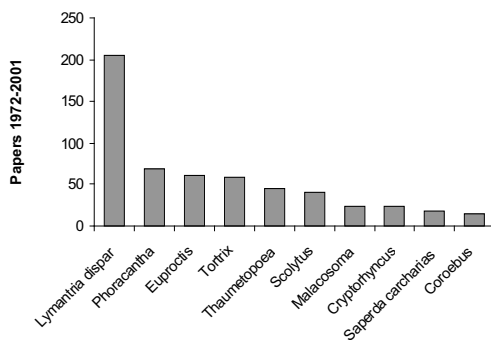


Fig. 4. Number of papers published during the period 1972-2001 on each main forest insect genus related to broadleaved tree species.

The number and type of research papers differ greatly from one country to the next, a reflection of either the distribution of different forest types (e.g. oak insects were primarily studied in the central and western part of the Mediterranean) or the presence of research institutes/staff specialized in forest entomology (e.g. INRA in France). Surprisingly, there are huge areas in the eastern part of the Mediterranean which have been neglected by forest entomologists.

General literature and activities related to forest entomology

In the past, literature devoted to forest insects in the Mediterranean countries was generally poor. There were some good textbooks in Central Europe, such as those by Ratzeburg (1844) and Escherich (1914-1942), but they did not cover the major insect species in southern countries. The first extensive contribution to the study of forest insects in the Mediterranean region was the *Traité d'Entomologie Forestière* by Barbey (1913 and 1925), rapidly followed by an adaptation in Italian (Cecconi, 1924). Schimitschek conducted a thorough survey of Turkey in 1944. This was followed by the publication of other research studies in other countries (Spain: Romanyk and Cadahia, 1992). The importance of an ecological approach to the study of forest insects was demonstrated by Dajoz (1980) and updated in 2000 (Dajoz, 2000).

Several well illustrated handbooks have been published in the last 20 years, covering insect pest species on a national scale (Portugal, Ferreira and Ferreira, 1990 and 1991; Spain, Hernandez and Perez, 1998; France, Abgrall and Soutrenon, 1991; Italy, Stergulic and Frigimelica, 1996; Albania, Laceja, 2001) or dealing with specific groups of insects (cone and seed, Roques, 1983; oak defoliators, Roversi and Luciano, 2001; poplar insects, Delplanque, 1998).

Monographs published with contributions from different authors on a given subject, often constituting special issues of forestry journals or proceedings of meetings, include research on biological forest control (France), processionary moths (Schmidt, 1990), cypress

pests (Roques and Battisti, 1999), gypsy moths (Mihailovic *et al.*, 1999), and Aleppo and brutia pines (Mendel, 2000).

Two important work groups dealing with forest insects were created in the Mediterranean region. The first was focused on the pine processionary moth, *Thaumetopoea pityocampa*, and was active during the period 1968–1978, under the supervision of P. Grison and G. Démolin. Three volumes of proceedings (*Boletín del Servicio de Plagas Forestales*, 1969 and 1970, vol. 12 and 13, *La Lutte Biologique en Forêt, Annales de Zoologie – Ecologie Animale*, Numéro hors série, 1971) and several papers were published. A second study group was organised within the framework of the OILB/IOBC in 1993 and devoted to "Integrated Protection in *Quercus* sp. forests", under the supervision of P. Luciano. Proceedings were published in 1995 and 1999 (Integrated Protection in Cork Oak Forest, IOBC/WPRS Bulletin, vol.18 and 22).

Current trends in research

Environmental issues

Preservation and improvement of biodiversity concerning forest insects has received little attention. Only five out of 205 papers on oak insects deal with diversity problems, and even less for pines, whereas a great deal of work is currently being done on similar problems in Central and Northern Europe, especially in boreal forests (Larsson *et al.*, 2001). Some saproxylic insects included on the red lists of threatened species in Europe (Speight, 1989) are considered to be pests in Mediterranean forests (e.g. the oak *Cerambyx*, Soria *et al.*, 1994; El Antry and Villemant, 1998), and this issue deserves further attention. The relationships between forest fires and insects may also be an interesting aspect of this issue since the conservation of species depends on the availability of burnt trees (Markalas, 1997) as well as on the regeneration dynamics of dry forest stands and the conservation of whole ecosystems.

The effects of global change on Mediterranean forests were predicted during the last decade (IPCC, 2001) and we are now seeing the first likely effects on forest insects, as has been observed elsewhere (Ayres and Lombardero, 2000). A clear example is provided by the pine processionary moth in both France (Goussard *et al.*, 1999) and Italy (Benigni and Battisti, 1999), where an expansion of the outbreak area is occurring at upper latitudes/elevations. The old problem related to the outbreak of the pest is now present under new host (*Pinus sylvestris* and *P. mugo*) and environment conditions.

Global change may also be related to the invasion of exotic pests. The pine wood nematode has already entered Portugal (Sousa *et al.*, 2001), where it is associated with *Monochamus galloprovincialis*. There is the need for risk assessment concerning the further spread of this disease and other potential infestations related to forest product trade (Roques, 2001). Moreover, climate change may further affect the introduction of new insects, especially those from tropical countries. The European Plant Protection Organization (EPPO) has a specific working group on the subject:
<http://www.eppo.org/QUARANTINE/forest/forest.html#nature>.

Pest management

Surveillance and monitoring of forest insect pests are being carried out in different countries with specific funds from various organisations (World Bank, FAO, EU, national and local administrations). Methods vary greatly among countries because they are adapted to local conditions. However there is the need to develop standard methods of monitoring such as those proposed by the IUFRO working group 7.03.10: Methodology of Forest Insect and Disease Survey in Central Europe. The proceedings of this work group (three issues published) also include some contributions from Mediterranean countries, but this specific target needs to be considered separately.

The Integrated Pest Management of forest defoliating insects in the Mediterranean is presently primarily focused on the use of preparations of *Bacillus thuringiensis kurstaki* in oak and pine stands, mainly against gypsy moth and pine processionary moth. The area treated annually may vary from a few hundred to several thousand hectares. In this context, and mainly when applications are repeated over the same area, management should be careful to avoid the selection of resistant insect strains such as the one that occurred in populations of *T. pityocampa* (Shevelev *et al.*, 2001), for example. The possibility of using tree genotypes selected for resistance to insects and pathogens can be a promising tool under some conditions, especially in plantations of maritime pine (Kleinhentz *et al.*, 1998) and in the landscape use of cypress (Roques and Battisti, 1999). The management of natural enemies at the ecosystem level (alternative hosts, tritrophic interactions) may provide new insights into these organisms, together with the understanding of the possible effects of global change and the expansion of the hosts. The use of natural enemies for traditional biological control of introduced pests is still a necessary practice in some cases, especially with eucalyptus pests.

Population studies

Recent advances in the population genetics of important pests such as *Matsucoccus feytaudi* (Burban *et al.*, 1999), *Tomicus* spp. (Kerdelhué *et al.*, 2002), *Megastigmus* (Auger Rozeberg and Roques, this volume), *Pissodes* (Roux Morabito *et al.*, this volume) and *Thaumetopoea* (Salvato *et al.*, this volume), have contributed to both solving taxonomic problems and identifying relationships of populations with host plants and geographic regions. These results may have an important impact on pest management, especially when the insect range is expanding. Another issue that deserves more attention is the chemical ecology of insect-plant relationships. Host preference is known in several systems (e.g. in *Pinus pinaster* and *Dioryctria silvestrella*; Jactel *et al.*, 1996) but underlying mechanisms need to be better understood and the resulting knowledge could possibly be used for management purposes. The constitutive and induced tree defence to insects has been analysed in some tree species (Lieutier *et al.*, 1989) but needs to be studied in several systems.

The study of tree defence often involves several different organisms which may mutually benefit from the association. Insect-fungus interactions are well-known in the bark beetles of pines (Lieutier *et al.*, 1989) but, recently, a new association was revealed for cone and seed insects, as in the case of cypress (Battisti *et al.*, 1999). Further cases to be considered include the possible interactions of insects with mycorrhiza and endophytic fungi.