Insect Pests of Fruit Trees and Grapevine

Minos Tzanakakis

Byron Katsoyannos

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Preface

The present book describes the morphology, life history, symptoms of injury to the trees, and ways and means of controlling insect pests of fruit trees or grapevine. It is particularly useful to university instructors teaching respective courses, to students taking such courses, and to fruit or grapevine growers and other persons involved in the growing or protection of fruit trees or grapevine from insect pests. The authors are university professors with particular experience in the respective field under the conditions of Greece. The insect species covered, and the literature consulted and cited, are mainly from countries bordering the Mediterranean Basin, yet a considerable number of them concerns also other countries having the Mediterranean climate or a mild continental one. The book is not a review of the respective literature, yet, the more than 700 references cited are a rich source of additional useful information. Authorship priority has been adopted wherever possible.

To assist readers recognize many of the species treated, and some of the symptoms of injury they cause to the trees, more than 400 color photographs and other illustrations are included. Many of them are from a previous book in Greek, with a similar title, by the same authors, published in 1998 by Agrotypos S.A. The source of each figure is given in the respective legend.

At the beginning of each chapter there is a list of the species which frequently or occasionally infest the respective group of trees in Greece and certain other countries. A black square preceding the name of a species on the list indicates that the respective species is treated in some part of the book. The sequence of species in the text is the one shown on the lists, i.e. according to order and family, and in alphabetical order within each family. For insecticides and other plant protection products the internationally adopted common names of their active ingredients are used as a rule, instead of commercial names of specific formulations.

Throughout the text “larva” is used for all preimaginal stages, between the egg and the adult, of all species of insects, whether ametabolous, hemimetabolous or holometabolous. In larvae, the term “stadium” is used for the period of time between two consecutive molts, i.e the period of time spent in any given larval instar. Therefore, after hatching from the egg, the first-instar larva remains in the first

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stadium until it molts. Subsequently, it becomes a second-instar larva and remains in the second stadium until its second molt, and so on.

In the past several years, the European Parliament and the European Council have taken decisions and issued directives to be followed by member states, for the reduction of the hazard from the use of agricultural pesticides to human health and the environment, as well as for encouraging the development and application of integrated plant protection programs. Based on those instructions, member states should further develop and apply their national plans. A fairly recent such directive is 2009/128/EK of the 21st October 2009, completing several previous ones. Among the actions included in those directives are the setting of maximum allowed concentrations of pesticide residues in and on food and feed of plant and animal origin, and rules regarding the marketing, storing, and application of agricultural pesticides. Institutions and individual scientists advising growers should be familiar with such European directives and national rules and limitations. It is encouraging that in a number of European countries there has been a substantial reduction of the use of classical insecticides in fruit orchards, and an increase of the application of methods and means compatible with integrated pest control.

It is well known that the effectiveness of insect control is affected by a number of factors. If the fruit grower does not take those factors into account when planning or executing insect control, effectiveness may be limited. As such factors in each particular orchard, season, and case are beyond the control of the authors, neither the publisher nor the authors have any responsibility whatsoever for possible low effectiveness against the pest insects, or for possible injury to the trees, their products, or other living organisms by the measures and means recommended in this book, whether chemical or other. Especially for chemical measures it is essential to carefully read, apply the instructions and take the precautions written on the label of containers. State authorities, based on international experience and regulations, as well as on local experience and conditions, update at intervals the texts of labels, and in general the allowed uses of plant protection products, including their maximum allowable concentration in the spray liquid, and the minimum number of days to elapse between the last application and harvest, so as to avoid unacceptable residues on or in the harvested product. Therefore, label instructions and the advice of pertinent local agricultural advisers

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or other authorized persons should be the guide to fruit growers planning to apply insect pest control in their orchards. Consequently, specific insecticides and other plant protection products mentioned in this book as effective against certain injurious insects, should be taken only as examples of effectiveness in the past, and not as current recommendations.

M.E.T.

B.I.K.

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Introduction

The protection of fruit trees from phytophagous insects and other animal pests (mites, nematodes etc.) to be effective, economical and safe, should be done with the proper strategies, using methods and means that are applied in the right way, after knowledge and consideration of the various factors that affect it. There are three main strategies of control: the one by calendar or schematic, the directed or oriented, and the integrated one. Among the methods of control are the chemical (with classical or other insecticides), the biological, the biotechnical and certain other methods. The measures of control include chemical, cultural, mechanical, legal, and other.

a. **By calendar or schematic control.** Frequent insecticidal sprays are carried out based on certain dates, or according to certain vegetative stages of the trees, irrespective of the presence or population density of pest populations. Usually wide spectrum pesticides are used. The spray programs are usually planned by companies producing and selling pesticides, or by state central or regional plant protection and grower-warning stations and less often by other agencies or organizations. This strategy is the easiest and simplest in its application, therefore, it is widely followed. Usually more sprays are carried out than needed. This results in a high cost and especially adverse effects on the environment and the beneficial organisms in the orchard. Because of the frequent use of insecticides, certain insects after a shorter or longer period develop resistance to certain of them. Resistance makes this strategy often ineffective after a longer or shorter period of time, depending on the pest species and the insecticide.

b. **Directed or oriented control.** It is based mainly on instructions given to the grower by the regional plant protection warning services. It consists of the timely control of certain pest insects only when they are in the orchard, and if it is estimated that they constitute a hazard to the crop in the particular year or season. The decision regarding the time of control is taken after monitoring the insect population with the proper technique and also taking into account weather and other data. Attempt is made to protect beneficial organisms such as insectivorous parasitic insects and predatory insects and mites, through whose action the populations of a number of pest insects and mites are reduced.

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When applying this strategy, the pesticides used are as much as possible effective against the primary pest species, but selective, so that they have the least harmful effect on the beneficial organisms and the environment.

c. **Integrated control.** In the last several decades, many definitions of integrated control or integrated pest management have appeared in the international literature. According to Kogan (1998), a respective survey recorded 64 definitions of integrated control, pest management or integrated pest management. The one adopted by an FAO panel of experts is: "Integrated pest control is a pest management system that, in the context of the associated environment and the population dynamics of the pest species, utilizes all suitable techniques and methods in as compatible a manner as possible and maintains the pest population at levels below those causing economic injury". Kogan (1998) points out certain weaknesses of this definition and suggests: "Integrated pest management (IPM) is a decision support system for the selection and use of pest control tactics, singly or harmoniously coordinated into a management strategy, based on cost/benefit analyses that take into account the interests of and impacts on producers, society, and the environment". In Article 3 of Directive 2009/128/EC of the European Parliament and of the Council of the European Union of 21 October 2009, "integrated pest management means careful consideration of all available plant protection methods and subsequent integration of appropriate measures that discourage the development of populations of harmful organisms and keep the use of plant protection products and other forms of intervention to levels that are economically and ecologically justified and reduce or minimise risks to human health and the environment. Integrated pest management emphasises the growth of a healthy crop with the least possible disruption to agro-ecosystems and encourages natural pest control mechanisms". According to another, generally accepted definition, integrated control or IPM is "a system of ecologically oriented management of the populations of organisms injurious to plants (insects, mites, fungi, viruses, weeds, etc.) which uses all suitable techniques and methods, in a combined way, so that the density of their population is kept at levels below those which could cause economic damage to the crop". A main aim of integrated control is the reduction of the use of those pesticides which are

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dangerous to the environment, the ecological (biological) balance and man on one hand, and the maximum use of methods other than chemical on the other (B. Katsoyannos and Koveos 1996). Integrated control does not necessarily use more than one method or technique of pest control. The number depends on the case. The most important requisites for integrated control to be applied properly are the following:

1. Knowledge of the bioecology of the primary and secondary pests of the tree and of their natural enemies, and especially the effective natural enemies.
2. Availability of control methods other than chemical.
3. Availability of a method for detecting the presence and for monitoring the populations of the various pests and the evolution of the injury they cause to the trees. Also, a method should be known for detecting the presence and progress of the population of beneficial insects and other organisms. The main methods or ways of following up insect populations are regular visual observations during winter and during the growing season, the knocking down (sondage) of insects and collection of them in special containers underneath, the sampling of plant parts (flowers, fruits, leaves, parts of twigs) to examine their degree of infestation, the caging in the field of infested plant parts to follow the development of the various stages of the life cycle of pest insects on them, the determination of the phenology of the pest insects on the basis of thermal summations (day-degrees) after a given date, and the use of effective insect traps. For the use of insect traps in fruit orchards see also B. Katsoyannos (1996a).
4. The setting of a “limit of tolerable population density” and a respective “intervention density” for every pest insect. The “limit of tolerable density” or “economic injury population level” (E.E.L.) is defined as the density of the insect population (or of the injury it causes) that if surpassed, the expected damage will be economically substantial. The “intervention density” or “intervention threshold” is the one at which control measures are taken, so that the E.E.L. is not surpassed. It is usually a little below the E.E.L., so that economic injury be avoided. To determine the above population densities, one has to take into consideration both the demands of the market (buyers), and other factors that may affect the level of insect populations, locally and with time. It is understood that the intervention density differs depending on the

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intended method of control (see also Tzanakakis 1995).

5. The incorporation of the various elements and factors that participate in integrated control in a system that can function in practice. More specifically, there is need for cooperation between the participating scientists, technicians and growers. The integrated control strategy is a dynamic system of ideas, techniques and methods of plant protection, which to be applied in practice requires the fulfilment of the above-mentioned conditions. Methods applied in the strategy of integrated control are the following:

a. **Chemical method.** Selective insecticides are used, such that do not eliminate the beneficial entomophagous and acarophagous arthropods. If there is no available selective insecticide on the market for the particular case, and chemical intervention is necessary, a non selective insecticide of short residual action is used at the smallest dose possible, and applied on the right surface and at the right time, so that a selective effect is reached. Among the insecticides that are selective, or that can be used in a way that gives a selective result are the microbial ones, certain ones with hormonal action, and some organophosphorous or carbamate ones of short residual action.

b. **Biological methods.** In these methods natural enemies of the pest species are used, especially entomophagous insects and mites, entomoparasitic nematodes, entomopathogenic microorganisms (bacteria, fungi) and viruses. Some authors include in the biological methods the use of microbial insecticides. A recent example of successful biological control in Greece, has been the control of the citrus woolly whitefly *Aleurothrixus floccosus* with the introduction and release in citrus orchards of its parasite *Cales noacki* (P. Katsoyannos 1994a).

c. **Biotechnical methods.** In this category are included methods and techniques that take advantage of certain characteristics of insect behavior. Among them are insect traps, when used for direct insect control, i.e. for “mass trapping”. Another method of special interest is the use of sex pheromones in “mating disruption”, i.e. in preventing the sexes from meeting and mating. According to this method, we place in the orchard a number of pheromone dispensers (evaporators). The pheromone is diffused over the orchard and causes confusion and disorientation of the males of the pest species, which thus are unable to meet the females.

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As a result the females lay infertile eggs. This method has been successful against certain moths which are serious pests of fruit trees and grapevine, such as the codling moth of apples (*Cydia pomonella*), the oriental fruit moth (*Grapholitha molesta*) and the European grape berry moth (*Lobesia botrana*). The review paper by Cardé and Minks (1995) regarding this method is worth consulting.

d. **Other methods.** There are also certain other methods that can be used in integrated control of fruit tree pests. The "sterile insect release" method is placed in the genetic methods of control by some authors, and in the biological ones by some others. The pest species is mass produced in specific installations, sterilized, and released in the specific area. The numerous sterile males released mate with unmated females of the natural pest population. The result is that most eggs to be laid give no progeny. The method is successful when applied over very large areas, but also in small but geographically isolated areas. It has been used successfully (alone or combined with other methods of control) against the Mediterranean fruit fly (*Ceratitis capitata*) in Israel, Mexico and elsewhere. The use of tree cultivars resistant to pests is usually placed in the cultural methods and means of control. The use of genetically selected races of beneficial organisms (resistant to pesticides) could well be included in the genetic methods, while the use of genetically modified insects or plants, with the use of genetic engineering could be considered as biotechnological methods of control. The use of genetically modified organisms, except difficulties of technical nature in their development, is confronted also with problems of social acceptance. In integrated control, where advisable, mechanical, cultural, and other measures are used.

The factors or conditions that affect the effectiveness of methods and measures of insect control are many. Some of them are: The knowledge of the identity of the pest insects, the degree of injuriousness, the degree of knowledge of the life history of the pests, that is of their way of life, of their development and behavior on the tree to protect, their way of life on other neighboring host-plants, cultivated or wild, the fluctuations of their populations, the likely development of resistance to certain insecticides, the proper application of control measures, and the need for simultaneous control of mites, fungi, bacteria or other plant pathogenic organisms of the given trees to protect.

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With scientific progress in the field, the measures of insect control and the strategies through which they are applied change with time. In several European countries there has been a substantial reduction of the use of classical insecticides against pests of fruit trees. Instead, other measures have replaced them within the frame of integrated control. In this respect, the contribution of the European Commission has been great. Through respective directives to member states, and the enforced exchange of information between member states as well as between them and the Commission, the protection of plant pests is achieved with less and less hazard to the grower, the consumer of plant products, the general public and the environment. Such a directive is Directive 2009/128/EC of the European Parliament and the Council of the European Union of 21 October 2009. This Directive "establishes a framework to achieve a sustainable use of pesticides by reducing the risks and impacts of pesticide use on human health and the environment and promoting the use of integrated pest management and of alternative approaches or techniques such as non-chemical alternatives to pesticides". Within the provisions of this directive, but also according to previous regulations of the European Council, member states will establish national rules to achieve the reduction of pesticide use through integrated pest management and organic farming. Another Directive: 2009/127/EC also of 21 October 2009, modifies a previous one concerning the equipment for the application of agricultural pesticides. In addition to their properties, proper maintenance and frequency of inspection, instructions are given on the ways such equipment should be used so as to minimize spray drift that endangers humans, beneficial organisms and the environment.

In Greece, the Ministry of Rural Development and Food, formerly Ministry of Agriculture, is the state agency responsible for putting into force the EC directives concerning pest control in agriculture, through state legislation. Such legislation takes into account local conditions and local experience. In addition, regulations and instructions are addressed to scientists responsible for advising and supervising growers so that fruit pest control be applied within the desired framework. One of the crucial tasks of the Ministry's Plant Protection Service is the updating of the list of pesticides that are permitted for use on each specific crop or against specific pests. Persons involved in pest control and especially those advising the growers should consult those lists of pesticides permitted in the

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country. They can be found online in the website of the Hellenic Ministry of Rural Development and Food, “www.minagric.gr”, in the menu “agricultural warning”, and also in other websites such as “www.agrotypos.gr” where a regularly updated database of registered pesticides in Greece is provided, “www.farmacon.gr”, and others. Also, in respective websites of other countries.

New knowledge may suggest recommendations regarding a new pesticide or, more frequently, the prohibition of a given one formerly used against a given species of insect or insects on specific fruit trees. The prohibition may concern not all but only certain ways or times of application of the given pesticide on a given species of fruit tree. Changes in the pesticides recommended for a specific use and prohibitions for certain of them are frequent. This is why we avoided recommending specific insecticides against most pest insects treated in the book. As a rule we mention only the chemical group or family of insecticides recommended in the past in the literature.

Persons involved in the protection of fruit trees from pest insects and other arthropods should keep in mind that in addition to its LD 50, volatility, stability under sunlight or humid conditions and other properties, additional factors may also affect the effectiveness of an insecticide in specific cases to the extent that it proves much more suitable against a certain pest insect than other members of the same chemical family. Therefore, mention of a given chemical may not be inappropriate in specific cases. However, as a rule the reader should not consider the insecticide(s) given in the text as the only effective ones, but rather as examples that refer to specific cases. Fruit growers should consult local farm advisers, other experts and respective information through the media, in order to apply the best insecticides recommended against specific pests in their area and case at each season.

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Insects of pome trees

Homoptera

- *Stictocephala bulalus* (F.), Membracidae[1]
- *Tettigoniella viridis* (L.), Jassidae
- *Metcalfa pruinosa* (Say), Flatidae

Psyllids

- *Cacopsylla mali* (Schmidberger), Psyllidae
  Cacopsylla melaneura Foerster, Psyllidae
- *Cacopsylla pyri* (L.), Psyllidae
- *Cacopsylla pyricola* (Foerster), Psyllidae
- *Cacopsylla pyrisuga* (Foerster), Psyllidae

Aleyrodoidea (whiteflies)

  Siphoninus granati (Priesner and Hosni), Aleyrodidae
- *Siphoninus phillyreae* (Haliday), Aleyrodidae
- *Parabemisia myricae* (Kuwana), Aleyrodidae

Aphidoidea

  Anuraphis farfarae (Koch), Aphididae
  Aphis gossypii Glover, Aphididae
- *Aphis nerii* Boyer de Fonscolombe, Aphididae
- *Aphis pomi* De Geer, Aphididae
  Aphis pyri Boyer de Fonscolombe, Aphididae
- *Aphis spiraecola* Patch, Aphididae
  Dysaphis devecta (Walker), Aphididae
- *Dysaphis plantaginea* (Passerini), Aphididae
- *Myzus persicae* (Sulzer), Aphididae
  Piraphis pirinus (Ferrari), Aphididae
  Rhopalosiphum insertum (Walker), Aphididae
  Yezabura malifoliae Fitch, Aphididae
- *Eriosoma lanigerum* (Hausmann), Eriosomatidae
- *Eriosoma lanuginosum* (Hertig), Eriosomatidae
- *Aphanostigma piri* (Cholodkovsky and Mokrzecky), Phylloxeridae

Coccoidea (scale insects)

- *Aspidiotus nerii* (Bouché), Diaspididae
  Epidiaspis leperii (Signoret), Diaspididae
- *Lepidosaphes ulmi* (L.), Diaspididae
- *Parlatoria oleae* (Colvée), Diaspididae
- *Pseudaulacaspis pentagona* (Targioni -Tozzeti), Diaspididae
  Quadraspidiotus ostraeformis Curtis, Diaspididae
- *Quadraspidiotus perniciosus* (Comstock), Diaspididae
  Quadraspidiotus piri Licht., Diaspididae

[1] On the list of species at the beginning of each chapter, certain names are preceded by a black square. They are the species treated in the respective chapter or in another part of the book. For the respective pages please consult the Taxa Index at the end of the book.

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- *Saissetia oleae* (Bernard), Coccidae

Pseudococcus viburni (Signoret), Pseudococcidae

Hemiptera

- *Calocoris fulvomaculatus* De Geer, Miridae
- *Calocoris norvegicus* Gmelin, Miridae
- *Calocoris trivialis* Costa, Miridae
- *Monosteira unicostata* Mulsant and Rey, Tingidae
- *Stephanitis pyri* (F.), Tingidae

Rhaphigaster nebulosa Poda, Pentatomidae

Thysanoptera (thrips)

Taeniothrips inconsequens (Uzel), Thripidae
Taeniothrips meridionalis meridionalis Priesner, Thripidae
Thrips minutissimus L., Thripidae

Coleoptera (beetles)

Anisoplia sp., Scarabaeidae

- *Anomala ausonia* Erichson, Scarabaeidae
- *Anomala dubia* Scopoli, Scarabaeidae
- *Anomala vitis* F., Scarabaeidae
- *Epicometis hirta* (Poda), Scarabaeidae
- *Melolontha melolontha* L., Scarabaeidae

Oxythyrea funesta (Poda), Scarabaeidae
Popilia japonica Newman, Scarabaeidae
Potosia aeruginosa Drury, Scarabaeidae
Potosia angustata Germar, Scarabaeidae
Rhizotrogus vernus Germar, Scarabaeidae
Valgus hemipterus (L.), Scarabaeidae
Agrilus sinuatus Olivier, Buprestidae

- *Capnodis tenebrionis* L., Buprestidae

Chrysobothris affinis F., Buprestidae
Cantharis obscura L., Cantharidae
Apate monachus F., Bostrychidae

- *Sinoxylon sexdentatum* Olivier, Bostrychidae

Teratolytta dives Brullé, Meloidae
Cerambyx scopolii Fuessly, Cerambycidae

- *Byctiscus betulae* L., Attelabidae

Haplorynchites caeruleus De Geer, Attelabidae

- *Involvulus cupreus* (L.), Attelabidae
- *Rhynchites (Coenorrhinus) aequatus* L., Attelabidae
- *Rhynchites aereipennis* Desbrochers, Attelabidae
- *Rhynchites bacchus* L., Attelabidae
- *Rhynchites lenaeus* Foerster, Attelabidae
- *Rhynchites pauxillus* Germar, Attelabidae
- *Rhynchites smyrnensis* Desbrochers, Attelabidae
- *Rhynchites versicolor* Costa, Attelabidae

Anthonomus pedicularis L., Curculionidae

- *Anthonomus pomorum* L., Curculionidae

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- *Anthonomus pyri* Kollar, Curculionidae
- *Anthonomus spilotus* Redtenbacher, Curculionidae
- *Curculio nucum* (L.), Curculionidae

  Magdalis barbicornis Latreille, Curculionidae
  Magdalis cerasi L., Curculionidae
- *Otiorrhynchus* spp., Curculionidae

  Phyllobius betulae F., Curculionidae
  Phyllobius oblongus (L.), Curculionidae
  Phyllobius pyri (L.), Curculionidae
  Polydrosus ponticus Faust, Curculionidae
  Ramplus pulicarius Herbst, Curculionidae
- *Scolytus amygdali* Guérin, Scolytidae

  Scolytus mali Becht., Scolytidae
- *Scolytus rugulosus* Mueller, Scolytidae
- *Xyleborus (Anisandrus) dispar* F., Scolytidae

  Xyleborus saxenesi Ratz., Scolytidae

Diptera (flies)

- *Apiomyia bergenstammi* (Wachtl), Cecidomyiidae
- *Contarinia pyrivora* (Riley), Cecidomyiidae
- *Dasyneura mali* Kieffer, Cecidomyiidae
- *Dasyneura pyri* (Bouché), Cecidomyiidae
- *Ceratitis capitata* (Wiedemann), Tephritidae

Lepidoptera (moths)

  Stigmella malella (Stainton), Stigmellidae
  Stigmella pyri (Glitz), Stigmellidae
  Stigmella pyricola Walker, Stigmellidae
- *Phyllonorycter blancardella* (F.), Gracillariidae
- *Phyllonorycter cerasicolella* (Herrich-Schaeffer), Gracillariidae
- *Phyllonorycter corylifoliella* (Haw.), Gracillariidae
- *Leucoptera malifoliella* (O.G. Costa), Lyonetiidae
- *Lyonetia clerkella* L., Lyonetiidae

  Conopia culiciformis L., Sesiidae
- *Conopia typhiaeformis* Borkhausen, Sesiidae
- *Synanthedon myopiformis* Borkhausen, Sesiidae

  Anthophila pariana Cl., Glyphipterygidae
  Agryresthia cornella F., Yponomeutidae
- *Yponomeuta malinellus* Zeller, Yponomeutidae
- *Yponomeuta padellus* (L.), Yponomeutidae

  Blastodacna putripenella Zeller, Cosmopterygidae
- *Anarsia lineatella* Zeller, Gelechiidae
- *Cossus cossus* L., Cossidae
- *Zeuzera pyrina* (L.), Cossidae

  Acleris variegana Denis & Schiffermueller, Tortricidae
- *Adoxophyes orana* Fischer von Rosslerstamm, Tortricidae

  Acrolita (Rhopobota) naevana Hübner, Tortricidae
  Ancylis selenana Gn., Tortricidae

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- *Archips rosanus* L., Tortricidae
  Archips podanus Scopoli, Tortricidae
  Archips xylosteanus L., Tortricidae
- *Cacoecimorpha pronubana* Hübner, Tortricidae
- *Cydia pomonella* (L.), Tortricidae
- *Grapholitha molesta* (Busck), Tortricidae
- *Hedya nubiferana* Haw., Tortricidae
- *Hedya pruniana* Hübner, Tortricidae
- *Laspeyresia pyrivora* Danilevsky, Tortricidae
- *Ectomyelois ceratoniae* (Zeller), Pyralidae
- *Euzophera bigella* Zeller, Pyralidae
- *Vanessa polychloros* (L.), Nymphalidae
- *Aporia crataegi* (L.), Pieridae
  Eriogaster lanestris L., Lasiocampidae
  Malacosoma neustria L., Lasiocampidae
- *Saturnia pavonia* L., Saturniidae
- *Saturnia pyri* Schiffermueller, Saturniidae
- *Euproctis chrysorrhoea* (L.), Lymantriidae
  Orgyia antiqua L., Lymantriidae
- *Lymantria dispar* (L.), Lymantriidae

Hymenoptera

- *Palaeocimbex quadrimaculata* (O.F. Mueller), Cimbicidae
  Janus compressus F., Pamphiliidae
- *Caliroa cerasi* (L.), Tenthredinidae
- *Hoplocampa brevis* Klug, Tenthredinidae
- *Hoplocampa testudinea* Klug, Tenthredinidae

***Stictocephala bubalus* (F.)** *(Ceresa bubalus, Centrotus bubalus, Membracis bubalus)* **(Homoptera, Membracidae)**, comm. **buffalo treehopper**

Adult. According to Balachowsky (1939), the body is pale green, with late-season individuals being brownish green. The average body length, from head to apex of the fore wing, is 10 mm. The shape of the body is characteristic. The pronotum is enormous, and along its middle forms a convex keel exceding the body in length and having a pointed processus terminalis. Seen dorsally, the pronotum widens laterally becoming triangular, and having a humeral horn on each side directed slightly backwards (Fig. 1). The wings are transparent, and the fore ones surpass the pronotum. The female has a strong contractile ovipositor able to cut through the bark of trees to insert the eggs.

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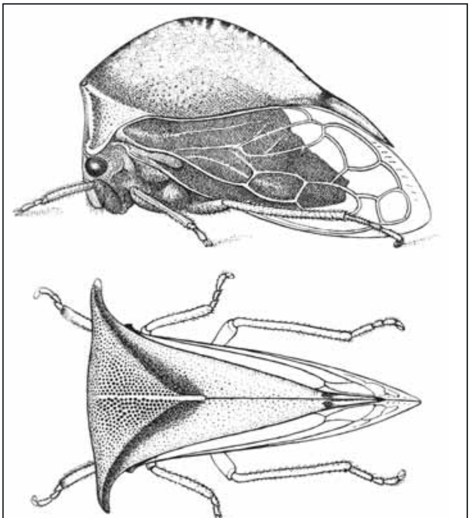
Egg. Whitish, 1.25-1.35 x 0.35-0.4 mm. The eggs, in small groups, are inserted in the subcortical layer of woody plants, mostly various fruit and forest trees. Pictures of such characteristic oviposition slits in shoots and twigs are given by several American and European authors such as Balachowsky (1939), Della Beffa (1961) and Kattoulas (1961) (Fig. 3).

Larva. The young larva is grey and 1-1.3 mm long. Along the dorsum of the thorax and of the abdomen it bears branched spines (Fig. 2). The grown larva is greenish or grey-green, bears also branched spines, is flat laterally, and is approximately as long as the adult.

Geographic distribution. North America and Europe.

Host plants. The larva does not harm trees. It is polyphagous, feeding on various herbaceous plants, such as leguminous ones, cotton, potato, carrot, beans and various other vegetables and weeds, as well as on ornamental plants such as dahlias and chrysanthemums. The injury to trees is due to the oviposition slits made by the ovipositing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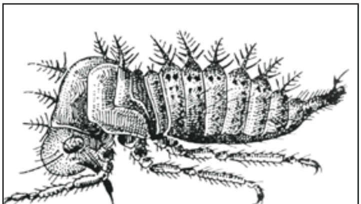
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Figs.1-3. *Stictocephala bubalus.*1.Adult in side view above, and dorsal view below (x10). 2.Larva in side view (Balachowsly 1939). 3.Oviposition incisions in apple twig made by the adult female (Kattoulas 1961).

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adult females to tree shoots and twigs (Fig. 3). Such injured trees are pome trees, stone fruit trees, grapevine, and many broad-leaved forest and amenity trees.

Life history and damage. It has one generation per year. It overwinters as an egg in the bark of shoots and twigs of various trees, in slits that the female makes with its ovipositor. In southern France (Balachowsky 1939) the larvae hatch in April and decend the trees to feed for approximately 3 months on herbaceous plants until mid-July, piercing and sucking their sap. After becoming adults and mating, the females fly to neighboring trees to insert their eggs, as mentioned above, in young, one- to two-year old trees, and one- to three-year-old shoots and twigs of older trees. The eggs are laid between the end of July and mid-October, but mostly in August to October. The lips of the slit almost close, and the eggs are not seen from the outside.

In central northern Greece hatching of the young larvae was observed mainly from mid-April to early May (Kattoulas 1961). In that region the larvae fed mostly on cotton and alfalfa growing under or very near trees. The larvae completed growth by mid-July, and adults were formed on the herbaceous hosts peaking in late July. The adult females flew mostly to apple and pear to oviposit. They selected shoots or twigs usually of small diameter and up to 3 years old. Before ovipositing, the female makes with its saw-like ovipositor a deep, 3 to 6-mm-long slit in the bark. The slit is approximately parallel to the shoot axis and in certain trees reaches or surpasses the cambium. In each slit the female inserts 7-14 eggs in one or two curved rows.

The oviposition slits made to the twigs of fruit trees and the formation of suberizing tissue around them by the plant, prevent the normal circulation of sap and the functioning of the twig which weakens. This affects the growth especially of young trees. In southern France damage was more important to young trees, and mainly in humid localities where adults concentrated in summer. Apple trees were more susceptible than pear ones (Balachowsky 1939). Larval feeding may sometimes also cause injury to herbaceous crops. When the larval population is dense, the loss of sap, together with tumors or lesions caused to the feeding sites result in limited growth and ultimate withering of the plants (Kattoulas 1961). Such injury was caused mostly to tender young cotton plants growing near fruit or other trees. In France, injury by larval feeding has been observed in chrysanthemums (Balachowsky 1939).

Control. To limit damage to young trees, the timely control of weeds

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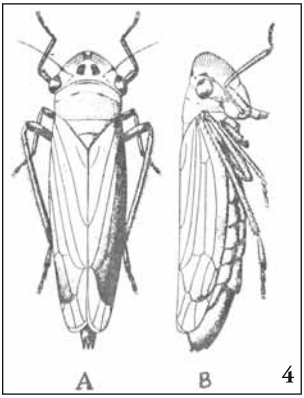
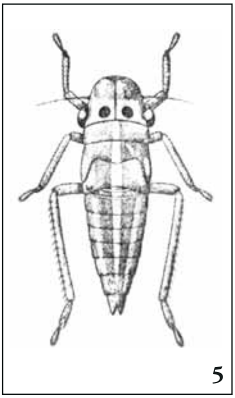
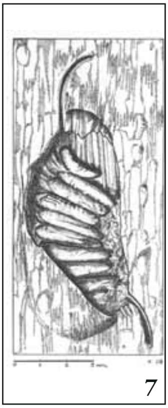
under and near the trees is recommended, so that the larvae find no hosts to feed on and develop. In winter, at the time of pruning, removing of twigs bearing slits will reduce the overwintering insect population. No burning of those twigs is necessary, because in cut-off twigs the eggs are soon dehydrated (Bonnemaison 1961). To reduce spread of the insect to other areas, the transfer of nursery trees bearing oviposition slits should be forbidden. In the case that nearby cultivated herbaceous plants are damaged by larvae, timely sprays with a synthetic organic insecticide, preferably systemic, are recommended. Against weeds, timely ploughing is often sufficient.

Tettigoniella viridis **L.** *(Cicadella, Tettigonia viridis),* **(Homoptera, Jassidae)**

Adult. According to Balachowsky (1941) the adult female is on average 9 and the male 5.5-6 mm long. The body is long and narrow and the head wider than the pronotum. The back of the body is green, the forewings dark green to blueish, while parts of the head, the legs and the ventral part of the body are yellow. There are two black spots in the median part of the vertex, between the two lateral ocelli (Fig. 4). Balachowsky (1941) gives pictures of adults and incisions made to pear and peach shoots housing the eggs.







Figs. 4-7. *Tettigoniella viridis.* 4.Adult female in dorsal and side view. 5.Larva in dorsal view. 6. Pear twig with numerous oviposition incisions (Balachowsky 1941). 7.Twig bark cut open to show the location of eggs (Kattoulas 1961).

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Host plants. The larvae feed and grow on Gramineae, especially *Cyperus, Arundo, Juncus, Pragmites* growing in humid prairies, especially near lakes, pools and rivers. The adults oviposit in the stems of neaby woody plants, including fruit and amenity trees of such genera as *Malus, Pirus, Cydonia, Prunus, Crataegus, Alnus, Populus, Quercus, Salix, Ulmus* and *Rosa.*

Life history and damage. According to Balachowsky (1941) it completes one generation per year in France. It overwinters in the egg stage. The eggs are inserted by the females in shoots and twigs of the various trees and shrubs seen above, in a way similar to that of the eggs of *Stictocepala bubalus* (above). There are 12-15 eggs on the average per oviposition slit (Figs. 6,7). The larvae (Fig. 5) hatch from the eggs usually in April. The neonate ones are dark grey. They decend to the graminaceous hosts, where they complete growth in approximately 2 months. After mid-June only adults are found in the fields. They feed little and remain in the low vegetation until September when they mature sexually. The females gradually abandon the prairies and congregate in neaby localities with woody plants such as orchards, gardens, parks and plantations of broad-leaf trees and shrubs to oviposit inside the stems, shoots or one- to three-year old twigs. Oviposition is more intense from mid-October to mid-November. This leafhopper was studied also in Bulgaria by Malkoff (1904). Bonnemaison (1961) mentions that Frediani (1956) observed in Italy 3 generations per year of this leafhopper, the adults appearing in late May, late July, and end of September. Certainly this needs verification, including correct species identification.

The injury caused by the oviposition slits in shoots of fruit trees, especially near humid localities may be serious, especially in young, up to three-year-old fruit trees. In such cases measures as against *Ceresa bubalus* (above) should be taken.

Cacopsylla mali (Schmidberger) (Homoptera, Psyllidae)

Adult. According to Balachowsky and Mesnil (1935) the males are 2.6 and the females 2.9 mm long. The general coloration is brown-red, but varies with the season and the individuals. The wings are transparent and exceed the end of the abdomen (Fig. 8).

Egg. It measures 0.4 x 0.16 mm. From whitish it turns yellowish or

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orange, and finally dark red (Fig. 9).

Larva. The young one is light yellow with red eyes and black vertical bands. In later instars it is uniformly greenish (Fig. 10).

Figs. 8-10. *Cacopsylla mali.* 8.Adult. 9.Eggs on the bark. 10.Last-instar larva on the underside of an apple leaf (photo A. Staub).

Geographic distribution. North and South Europe, the Balcans, Caucasus, Japan, Australia. Along the Mediterranean coast it is rare, while in central and northern Europe it is abundant and harmful.

Host trees. Mainly apple, and exceptionally pear, quince and *Sorbus* sp.

Life history and damage. It completes one generation per year. It overwinters in the egg stage on the bark of the shoots of the year, usually near buds. The larvae hatch in spring from April on, and attack buds, leaves, flowers and fruits. The adults are formed in May-June and oviposit in autumn (September to November) on the distal part of the shoots of the year. The eggs are partially inserted in the bark. According to certain authors (Balachowsky and Mesnil 1935 and references therein), the adults in summer migrate to other trees such as elm, and in autumn return to the apple orchards to oviposit. When the population density of this psyllid is high, normal bud development is adversely affected, and chlorosis, withering, petal fall, and drying of flowers, as well as abnormal fruit development may result. In addition, the honeydew excreted by the larvae and the resulting sooty mold, soil the fruits and add to the damage.

This psylla has many natural enemies, Hemiptera, Diptera,

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Coleoptera and Hymenoptera, and often the fungus *Entomophthora sphaerosperma* Fres.

Control. Satisfactory results have been reported by spraying the trees in late autumn to mid-winter with mineral or vegetable oils against the eggs. Such treatments may also kill aphid eggs, scale insects, and certain other insects that overwinter on the bark. Against larvae during the growing season, synthetic organic insecticides, fortified or not with a summer oil, are used. Whenever possible, it is advisable to combine the control of this psylla with that of codling moth.

***Cacopsylla pyri* (L.)** (*Psylla pyri*) **(Homoptera, Psyllidae)**, comm. **pear psylla**

Adult. It resembles a small cicada (Fig. 11). The adult of spring and summer generations is 1.2-2.7 mm long, and of rust color, while that of the autumn generation, which overwinters, is larger and darker.

Egg. Oval, whitish or white-yellow (Fig. 12), with a terminal filament which is shorter than the egg width.

Larva. There are 5 larval instars. Their body is flat, yellowish, with light brown or dark brown spots (Fig. 13). During the first 4 stadia the larval body is covered by a drop of honeydew which the larva excretes. This honeydew reduces the efficacy of insecticidal sprays.

Host plants. Pear. This psylla is considered as the main pest of pear trees in Europe (Bués et al. 2000).

Life history and damage. In the Larissa area of central continental Greece 4-6 generations per year are reported (Broumas 1990) and in the neighboring Magnesia 5-6 (Stratopoulou and Kapatos 1992c). It overwinters as adult in protected sites on the trees, on fallen dead leaves, and in other sites of the orchard. In Magnesia, on trees of the cultivar Crystali (Tsaconica), a considerable percentage of the females that have overwintered matures reproductively and oviposits in February and March, with a peak the first 10 days of March. The larvae hatch when the mixed buds of the cultivar Crystali start developing (Stratopoulou and Kapatos 1992c). They enter the developing buds and feed by piercing and sucking the bases of young leaves and the flowers. Later they move to the leaves, where they settle and cover themselves with the droplets of honeydew they excrete. The maximum population of 4th and 5th instars aqpproximately coincides

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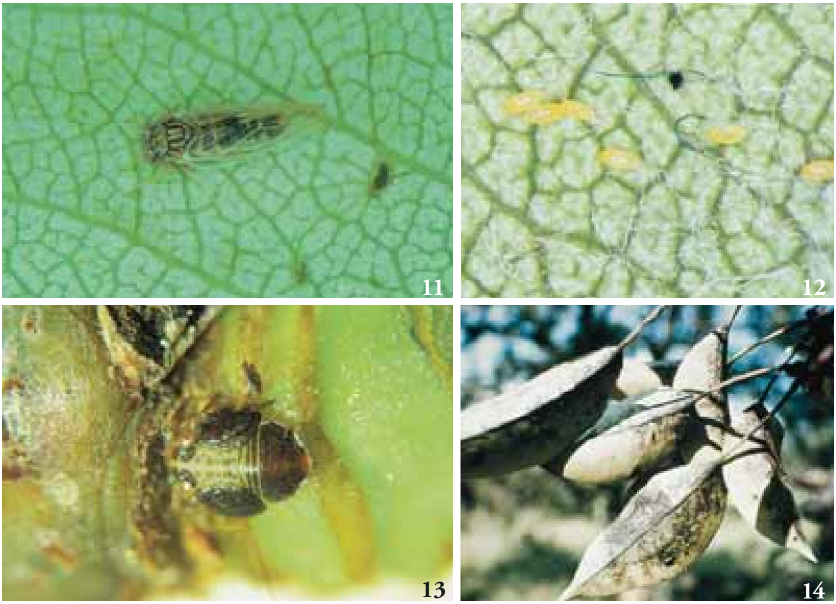

Figs. 11-14. *Cacopsylla pyri.* 11.Adult. 12.Eggs on the underside of a pear leaf (photo N.T. Papadopoulos). 13.Last-instar larva (photo N.D. Papadopoulos). 14.Sooty mold over larval honeydew on pear leaves A.U.T.).

with petal fall of the cultivar Crystali, usually in late March to mid-April. Adults are formed throughout April. The sites of oviposition differ with the season. In Magnesia, on Crystali pear trees, the eggs of the first generation were laid mostly at the base of mixed buds, whereas those of the second generation maily on leaves from mixed buds and on leaves of young shoots of the season (Stratopoulou and Kapatos 1992b). On the leaves the eggs are deposited usually in rows, and most of them on the lower leaf surface along the midrib.

In Magnesia, on Crystali trees, the first generation develops from February to April and is distinct. From mid-April until mid-August three generations are completed which overlap to a degree that varies with the year. From mid-August to late November a fifth generation develops, while part of its population, instead of entering diapause produces the 6th generation (Stratopoulou and Kapatos 1992c). In late September to early October starts the appearance of adults of the winter form, which have a dark color and enter a reproductive diapause. However, eggs and larvae are seen even in November. The

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population density is low in the first generation, but very high in May-June. In summer it drops and in autumn it rises again. Stratopoulou and Kapatos (1997) give for that area the duration of the egg stage and the five larval stadia from February through August, and their close correlation with the mean daily temperature.

Larvae and adults suck the sap of leaves, shoots and fruit. Their honeydew favors the establishment of sooty mold fungi (Fig. 14) and necrosis often occurs at the leaf site under the larva and its drop of honeydew. The symptoms of infestation by this insect include necrotic spots on leaves, sticky fruits, sooty mold, delayed growth, chlorotic foliage, and even leaf drop. In addition, this insect is difficult to control. Therefore, it is considered one of the most serious enemies of pear trees.

In Magnesia, according to Kapatos and Stratopoulou (1997) high psylla egg mortality was due mainly to the action of Anthocoridae predators. Those predators proved to be an important limiting factor of the psylla population during summer, and in combination with the high summer temperatures which were unfavorable for the larvae, they were able to contain the infestation of the trees to low levels during summer. On the contrary, the absence of high populations of those predators in May, is one of the reasons why the psylla population is especially high during that month. In April 1981, a heavy infestation of pear psyllas (the species not identified) was observed by the senior author on a few unsprayed pear trees of the Aristotelian University of Thessaloniki Farm. Larvae were abundant on shoots and leaves. Honeydew covered practically all the foliage and sooty mold started developing on some parts of it. At that time, a number of larvae and a few adults of the lady beetle *Coccinella septempunctata* were noticed on those trees and on nearby herbaceous *Sinapis* sp. Ten days later, the senior author could not find a single psylla on the pear trees, while numerous lady beetle adults were running up and down the trees searching for prey. By the end of July not a single psylla larva or fresh honeydew were detected. In July the lady beetle adults had abandoned the pear trees. This is a striking case of the effectiveness of an insectivorous lady beetle in controlling a pear psylla.

Control. It is difficult, because the insect develops relatively soon resistance to many insecticides. Also, if the insecticide does not possess the necessary volatility and the spraying is not done carefully, it does not penetrate the developing buds and, therefore, does not kill a high percentage of fist-generation larvae. This is why one spray in late

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Figs. 15-16. *Anthocoridae.* 15.Anthocorid adult (photo U. Remund). 16.Anthocorid larva in a colony of olive psyllas (photo N.T. Papadopoulos).

winter against the adults is necessary, and usually three sprays the period April to June with selective insecticides against the larvae or even the eggs. Sprays after late June should be avoided, to allow the natural enemies of psylla to act, especially predatory Hemiptera of the family Anthocoridae (Figs. 15, 16), such as the species *Anthocoris nemoralis* and *A. nemorum*, as well as Neuroptera, Diptera and Coleoptera, which have dense populations during the warm season.

In orchards of Magnesia the following spray program gave good results (Stratopoulou and Kapatos 1992a): first spray in mid-February, shortly before or just after the start of oviposition by the overwintered females. Winter oil sprays together with an organophosphorous insecticide are used, or a synthetic pytethroid. This spray, which kills adults and eggs, or also young larvae, reduces substantially the population of the first generation that follows. The second spray is done at petal fall, with a juvenile hormone mimic, such as fenoxycarb. This spray kills developed larvae (L4 and L5) of the first generation. Depending on population density, the second spray may be carried out later, towards late April or early May, with a substance preventing ecdysis, such as diflubenzuron, teflubenzuron or triflumuron, or with a selective insecticide-miticide such as amitraz, which is mild to entomophagous insects. The third spray is done in late May with a juvenile hormone mimic such as fenoxycarb or methoprene, or with a substance preventing ecdysis (above). The fourth spray, towards late June, is done also with a hormone mimic or

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an ecdysis blocker. The third and fourth sprays are usually combined, or can be combined with those against the codling moth. For details see Stratopoulou and Kapatos (1992a,b).

Based on observations in the neighboring area of Larissa, Broumas (1990) suggests sprays in four periods: 1) January-February, 2) from pear bloom to mid-June, 3) from mid-June to harvest (with amitraz, fenoxycarb or ecdysis-blockers), 4) in autumn, before leaf fall (with synthetic pyrethroids). The Plant Protection Forecasting Services follow the population density of the insect and the degree of ovarian maturity of female psyllas during the growing season, and advise the fruit growers regarding the proper time to spray. In central and western northern Greece, the periods of activity and reproductive maturity of adults that have overwintered, of oviposition, and of appearance of developed larvae (L5), in relation to the stages of development of the tree and, therefore the recommended periods of insecticidal interventions are close to those of the Larissa area (above). For each main fruit production area of the country the periods of intervention are determined by the respective Plant Protection Forecasting Service (for details see Kyparissoudas 1994). For the way to sample the preimaginal psylla population to determine if and when to spray, see Stratopoulou and Kapatos (1992a,b).

Bués et al. (2000) mention that although integrated pest management is applied more and more in European pear orchards, organophosphorous and pyretroid insecticides are still used increasingly, and resistance to them has developed in many psylla populations. With respect to measuring resistance, they point out that the overwintering generation, probably because of diapause, is more tolerant of insecticides than the summer generations.

In Greece, two more species of psyllas can be found on pear trees. They are: *Cacopsylla pyricola* (Foerster) which is polycyclic, and *C. pyrisuga* (Foerster) which is monocyclic. They may co-exist in the same orchard with *C. pyri*, but in such case their populations are sparse. In northern Greece, H. Riedl (personal communication) found in 1980 in pear orchards almost exclusively *C. pyri*, while on wild pears (*Pyrus amygdaliformis*) *C. pyricola. C. pyrisuga*, infests also apple and quince trees. It is larger than the other two species, the adult being 3.5-4 mm long. It is migratory. It overwinters on forest trees and flies to fruit trees in spring. It is an occasional and not serious pest of pear in certain localities of central Europe. Balachowsky and Mesnil (1935) give characters of male genitalia to distinguish the

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three species of psyllas that usually infest pear trees in Europe.

Whiteflies (Homoptera, Aleyrodidae)

They are tiny insects, easily recognized because their body and wings are covered with a fine white waxy powder, giving them the common name “whiteflies”. They have piercing-sucking mouthparts. The first-instar larva has developed legs and can walk. The next two instars do not have legs and cannot move. Plant injury is due to the removal of sap and contents of plant cells and to the abundant honeydew they excrete. This honeydew favors the development of sooty mold fungi which reduce the photosynthetic capacity of the foliage and also soil the fruit, thus lowering their commercial value. Some species may develop to serious pests of fruit trees where cultural conditions favor them, and where their effective natural enemies are absent or have been annihilated by the excessive and careless use of unsuitable insecticides in the orchard. The three species of this family most destructive in Greece, infest citrus trees and are treated in the respective chapter.

***Siphoninus phillyreae* (Haliday)** *(Trialeurodes inaequalis)* **(Homoptera, Aleyrodidae)**, comm. **ash whitefly**

Adult. It is 1.8 mm long and yellowish. The body and wings are covered with a white waxy powder, so it superficially looks white. According to Grandi (1951) the adult has a basic grey color, with stripes on the abdomen.

Larva. The larvae are oval, flat, with white waxy tufts on the back. The 4th instar larva has many cylindrical waxy protrusions.

Host trees. *Crataegus, Fraxinus, Pyrus (apple, pear), Mespilus, Rhamnus, Phillyrea,* and in southern Italy seldom the olive tree (Silvestri 1939). In northern and central Greece and on the island of Euboea, this polyphagous whitefly was observed on pome trees and *Crataegus* (Costacos 1963), and on pomegranate *(Punica granatum)* (Tsagkarakis 2012). In Cyprus is was recorded on pomegranate, causing yellowing and drying of leaf tissue, and also on pear (Georghiou 1977).

Life history and damage. According to Golfari (from Grandi 1951), this polyphagous species completes 3-4 generations per year in Italy.

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According to Costacos (1963), it completes 4 generations in Thessaly (central Greece). The eggs are deposited as a rule on the lower leaf surface, in groups of 10-20. Before egg laying, the female spreads a white waxy powder over the oviposition site. The young larvae spread on the foliage and each selects a suitable site on the underside of a leaf, where it settles. The other larval instars remain on that site. In Italy, incubation in spring lasts 8-17 days and the larval stage 30 days, whereas in summer the larval stage lasts 20 days. Golfari found in the first two generations only parthenogenetic females, while in the last two also males. According to Costacos (1963), the maximum of population density of this insect on pome trees in Thessaly was observed the first half of June. Sap loss weakens the tree and may result in early leaf drop and reduction of fruit size. Furthermore, soiling of the fruit by the insect's honeydew and interference with photosynthesis by the development of sooty mold fungi that follow, add to the damage. Costacos (1963) recorded in Thessaly up to 50% early leaf drop in pear trees infested by this whitefly.

Grandi (1951) gives four entomophagous insects which were recorded as natural enemies of *S. phillyreae* in Italy. Stocks and Hodges (2010, cited by Tsagkarakis 2012) give several more.

Control. Costacos (1963) states that when control with insecticides involved a relatively small acreage, the trees were not free of the whitefly, because of reinfestation from unsprayed neighboring trees. This is why he recommended that spraying be carried out synchronously over as large an infested area as possible. During an outbreak of this insect on apple and pear, in the area of Campania Italy, Tremblay (1969) tested for 2 years nicotine sulphate, azinphosmethyl, endosulfan, and mixtures of organophosphorous and carbamate ones against this pest. He also recorded the toxicity of those insecticides to 2 parasitic and 2 predatory natural enemies of the pest. None of the insecticides he tested was effective against the eggs of the whitefly, but most of them were highly effective against "young" stages (probably early-instar larvae) of the whitefly, but also against its 2 predatory species. He concluded and suggested weekly inspections for the early elimination of adult white flies, and the inclusion of the control of this pest in the integrated pest management programs for apple and pear trees.

In Egypt and Israel, the pomegranate, the pear and the quince are infested by another species of whitefly, *Siphoninus granati* (Priesner and Hosni). A polyphagous whitefly, *Parabemisia myricae,* which

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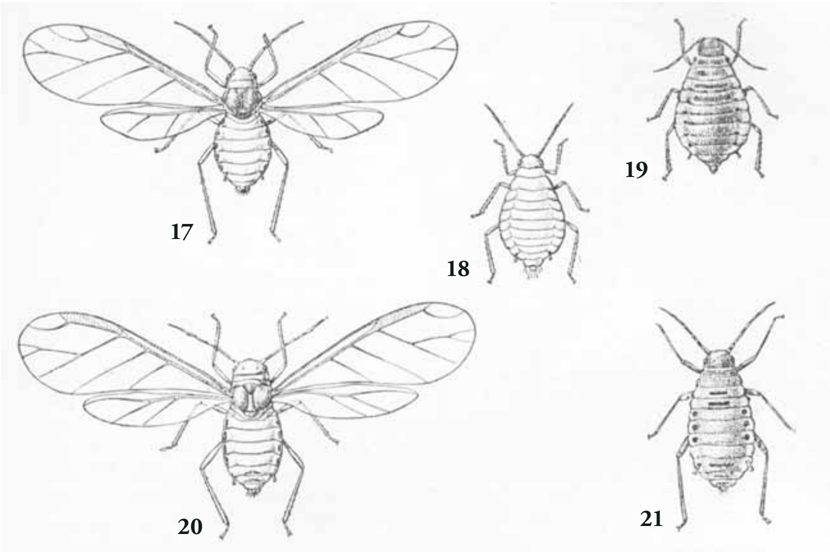
infests also pome trees in Europe is treated in the chapter on insects of citrus trees.

Aphidoidea (aphids, phylloxeras and related species)

To this superfamily of Homoptera belong many enemies of fruit trees. They are of small size and soft body, with fine legs and tarsi with two articles, and antennae from one and up to six articles (Figs. 39, 224). The winged forms (Fig. 17, 20, 225) have two pairs of transparent wings. Most species are polymorphic. In some species the number of different forms is great. Different forms occur in different generations or (certain forms) even in the same generation. The most usual forms are: apterous (Fig. 22), winged, with developed or rudimentary mouth parts, and individuals of the same sex differing in their reproduction, such as females which are viviparous and parthenogenetic, and others which are oviparous and fertilized (Figs. 17-21). In their reproduction occur viviparity, parthenogenesis,



Figs. 17-21. Various forms of adults of the aphid *Aphis maydis-radicis* Forbes, as seen dorsally. 17.Winged viviparous female. 18.Wingless (apterous) viviparous female. 19.Wingless oviparous female. 20.Winged male. 21.Wingless male (R. Stazione di Entomol. Agrar. Firenze (Sta. Firenze)).

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bisexual reproduction and generations with a few or no males. As to habits there are: 1) alternation of host plants (migration to other species of plant or plants), 2) different ways of living on the same species of host plant (e.g. phyllobious and rhizobious), 3) Different ways of life in individuals of the same generation. All above cases may occur in one species, however, in most species only some do. In species with two host plants, the "full" reproductive annual cycle occurs on the primary host, and the "migratory" annual cycle on the secondary host. In the migratory species the following types or morphs of individuals are mainly observed, in sequence beginning from spring: 1) *Fundatrices* (foundatory). They come out of the winter eggs, on the primary host. They are usually apterous parthenogenetic females, oviparous or viviparous. They develop in spring on the primary host. 2) *Fundatrigeniae*. They are apterous parthenogenetic female descendants of the *fundatrices.* They are produced usually from spring to autumn and live on the primary host, completing there more than one generations. 3) *Migrantes* (migratory). They are produced in more than one generations on the primary host, together with the *fundatrigeniae,* but usually after the first generation. They are winged parthenogenetic individuals and migrate to the secondary host plant where they give birth to progeny. 4) *Alienicolae.* They are born on the secondary host in more than one generations, from spring to autumn. They are descendants of the migratory forms and are parthenogenetic apterous or winged. The winged ones may migrate to other plants of the secondary or the primary host. 5) *Sexuparae* (to bear sexual forms). They are parthenogenetic winged or apterous, oviparous or viviparous. The eggs giving females are larger. The *sexuparae* are born usually on the secondary host and are progeny of the last generation of *alienicolae.* In late summer to autumn the winged ones migrate to the primary host where they bear the sexual individuals. The apterous *sexuparae* (in the species where this occurs) bear on the secondary host winged males which will migrate to the primary host. 6) *Sexuales* (sexual or amphigonic) i.e. males and females. They occur only once a year, usually in autumn. The females are almost always apterous and are born on the primary host from the *sexuparae.* After mating they lay one or a few winter eggs. The males which are born on the primary host are also apterous, while those born on the secondary host (in the species where this occurs) are winged and migrate to the primary host to mate there with the females. The *sexuales* have as a rule vestigial mouth parts and do not

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feed.

In the migratory species overwintering takes place in the egg stage as a rule. However, in regions with mild winters it is possible that other stages of the life cycle also overwinter, especially the adult parthenogenetic female, usually on the secondary host and less often on the primary host. Therefore, it is possible that some species may live uninterruptedly on a secondary host or hosts without the intervention of a primary host. The physiological mechanisms that regulate and/ or influence the alternation of hosts and the formation of winged or apterous forms in the Aphidoidea are not fully understood. Among the factors that intervene are temperature, photoperiod, crowding, and the physiological condition of the developing host-plant. These factors act on the individual insect whose form they determine, but may act also on its mother. The more than 3600 species of Aphidoidea are classified in 3 families, Aphididae, Phylloxeridae and Adelgidae (Chermesidae), or more often in 7 or 8 families.

Aphididae (aphids, plant lice)

They are well known to the grower and the average citizen under the common names plant lice or aphids. They are small, soft-bodied insects, usually 1-3 and seldom up to 7 mm long. They take up plant sap via a stylet bundle. This bundle consists of two pairs of needle-like stylets (the inner maxillary and the outer mandibular), which are held in a long sheath, the rostrum or proboscis, which is the modified labium (Miyazaki 1987). Their antennae consist of 3-6 articles. For details in aphid morphology see Barbagallo (1985), Miyazaki (1987), and references therein. Except the morphological characteristics of the superfamily Aphidoidea where they belong, most aphids have on the dorsum of the 5th and near the 6th abdominal segment a pair of tube-like appendages called siphons or ceratia, and at the end of the abdomen an apophysis called cauda (tail) (Fig. 22). The siphons are openings of glands that produce alarm pheromones. When the aphid is attacked by a predatory insect or other animal, it releases pheromones of a waxy nature which cause dispersal of the nearby aphids. Waxy droplets emitted by the siphons of certain species of aphids are also considered to discourage enemies by agglutinating their appendages. In some aphids the siphons are of much reduced size, being only openings or lacking altogether. Aphids are often pulverulent due to waxy exudates, either of powdery, filamentous, plate-like, or rod-like

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Fig. 22. *Megoura viciae* wingless adult (photo S. Keller).

appearance.

The aphids live mostly on tender shoots and tender leaves of various plants. They insert their mouthparts which are slender and long into the plant tissues and suck the sap. Certain species are rhizobious (root-living), or phyllobious and rhizobious, and many are cecidobious, i.e. they live inside galls that they create in the foliage of their host plants. They live usually in groups, one close to the other, with the head usually facing the basis of the shoot or leaf. In spring, their colonies may cover the whole apical part of young shoots of certain plants. The females of the parthenogenetic generations are viviparous, while those of the sexual ones are oviparous.

In aphids we observe the various morphs that we already mentioned in the superfamily Aphidoidea where they belong. With respect to the annual life cycle, the various aphid species, are distinguished into migratory and non-migratory. In the **migratory** at least two host-plants are necessary: the primary host where the insect develops sexually and asexually, and the secondary host where the aphid develops only asexually (parthenogenetically). On the primary host mating takes place and the winter eggs are laid. It is possible for certain species to have more than one species of primary and secondary hosts. In the **non-migratory** species the annual cycle is completed only on the primary host (on the same plant or on plants of the same species or of related species). If winged individuals disperse to other species of host plants, this is of no importance for the survival of the given aphid species.

Aphids are abundant mostly in spring and autumn, and generally in periods with mildly warm and humid weather. In spring the parthenogenetic females reproduce very fast. Spring weather and the availability of abundant tender leaves and shoots favor their development in climates such as that of Greece. The hot and dry summer months do not favor continuous reproduction of many harmful aphid species and their populations are very limited during

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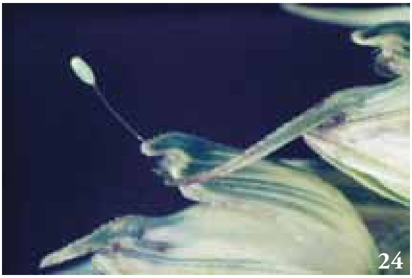
such periods. Their location on the plant, the density and shape of their colonies, as well as the kind of obvious injury to the plant (chlorosis, curling of leaves, deformation of plant organs, tumors, galls etc.) are characteristic in certain species or groups of species, and can help to species identification, in combination with the aphid's morphological characteristics. The proximity of secondary or of primary perennial host-plants, such as for example reeds (*Arundo* sp.) and wild reeds (*Phragmites* sp.), where certain species of aphids overwinter, may affect, positively or negatively, the population density of aphids on fruit trees.

Damage. The aphids remove a large quantity of plant sap and the feeding of many species causes leaves to curl. This protects the aphids from insecticidal spray liquids and makes their control difficult, if it is not done in time, i.e. before leaves curl. The abundant honeydew excreted or, in other words, eliminated by certain species of aphids soil the plant and the fruit, and favor sooty mold and ants that protect the aphids by deterring aphidophagous insects. Honeydew is typically disposed of by coating each droplet in powder wax and then projecting it away from the body (Malumphy 1997). Aphids is the major insect category which vectors plant pathogenic viruses. No other category of insects and more generally of arthropods transmits (vectors) so many and serious viruses to plants. They transmit non-persistent, semi-persistent and persistent viruses (for the minimum



Figs. 23-25. *Aphidophagous Neuroptera Chrysopidae.* 23.Adult. 24.Stalked chrysopid egg. 25.Larva sucks the haemolymph of an aphid (photo S. Keller).

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time of acquisition, the duration of infectivity, the minimum time for transmition by the aphids of the various categories of plant viruses and related subjects see Katis 1996). The usually dense aphid populations, the great number of generations they complete per year, which often exceeds 10, and the transmission of viruses to plants, place the aphids among the most destructive enemies of cultivated plants. Why, under natural conditions, the aphids do not destroy plant production, is due in large part to their many and effective natural enemies.

Natural enemies. Among the effective natural enemies of aphids are predatory Neuroptera of the families Chrysopidae (Figs. 23-25) and Hemerobiidae, predatory Coleoptera of the family Coccinellidae (Figs. 26-28), such as *Adalia bipunctata* (Figs. 44, 45) and *Coccinella septempunctata* (Figs. 31, 32), predatory Diptera of the family Syrphidae (Figs. 33-35) and parasitoid Hymenoptera of the families Braconidae, Chalcididae and Proctotrypidae. Species of the subfamily Aphidiinae (Figs. 36, 37) are common, and can cause heavy mortality to such aphids as *Eriosoma lanigerum, Aphis gossypii* and *Toxoptera aurantii.* Entomopathogenic fungi of the genus *Entomophthora* (Fig. 38) are effective under high relative humidity conditions, but not in the open in Mediterranean countries.

Control. It is done usually with chemical means (insecticides). To be effective, it should not eliminate beneficial aphidophagous insects and other arthropods, which complete the action of insecticides in a way that control becomes economical, lasts long, and does not cause the early development of aphid populations resistant to insecticides. For foliage sprays, certain organophosphorous and carbamate insecticides are used successfully. We can separate them in two categories. In the first belong chemicals which, although acting by contact, are able to enter the leaves and act also as stomach poisons against aphids that pierce and suck the contents of parenchymatic cells. These insecticides can, therefore, kill aphids even if they are in curled leaves and protected from the spray droplets. Tremblay (1985) mentions the organophosphorous and carbamate ones belonging to this category during those years. In the second category belong the definitely systemic aphidocides, most of them organophosphorous. They act by contact and as stomach poisons against aphids that suck sap. They are absorbed by plant tissues and are carried also to parts of the foliage not reached during the spray. Most of them have considerable toxicity to humans. Of the insecticides of the above two categories preferable are those that do not penetrate parasitized (mummified) aphids so as

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Figs. 26-32. *Aphidophagous Coleoptera Coccinellidae.* 26.Egg mass. 27.Two larvae near aphids. 28.Pupa on a leaf. 29.Adult *Adalia bipunctata.* 30.Dark-colored morph of *A. bipunctata* (photo S. Keller). 31.*Coccinella septempunctata* adult (A.U.T.). 32.Adults of *C. septempunctata* on peach (photo B.I.K.).

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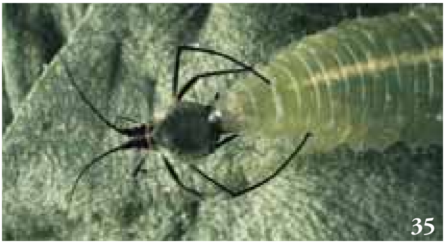

Figs. 33-35. *Aphidophagous Diptera Syrphidae.* 33.Adult sucking nectar. 34-35.Larvae sucking aphids (photo S. Keller).

Figs. 36-37. *Aphidophagous Hymenoptera Aphidiinae.* 36.An adult inserts an egg in an aphid. 37.Parasitized (swallen) aphids (photo S. Keller).

to kill the beneficial parasitoid Hymenoptera inside them. Also those having a relatively short residual action on plant foliage, so as not to kill parasitoid and predatory aphidophagous insects that come to the sprayed foliage a few days later. Such aphidocides that allow survival of aphidophagous insects in Italy are mentioned by Tremblay (1985). Each of those insecticides had a different toxicity to certain groups and species of aphidophagous and acariphagous arthropods (for certain of them, data from Fisher-Colbrie are given by Lykouressis 1992). Therefore, the aphidocide to be preferred will depend on which aphidophagous insects are dominant in our area, and whether we should control also phytophagous mites at the same time.

To determine the time of intervention, the terminal growth of the trees is examined (certain number of shoots or other organs per

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Fig. 38. Aphids infected by a fungus of the genus *Entomophthora* (the pink ones), and healthy (the green ones) (photo S. Keller).

given number of trees of the orchard) and the number of those infested by aphids is recorded. We spray as soon as the percentage of plant organs with aphids reaches or surpasses the intervention threshold. Examples of intervention thresholds from Italy and French Switzerland, given in sources referred to by Tremblay (1985) are:

– Apple: *Dysaphis plantaginea* 1-2%, *Aphis pomi* 10-15%, *Eriosoma lanigerum* 8-10%.
– Peach: *Myzus persicae* 7%.
– Citrus: *Toxoptera aurantii* 25%, *Aphis spiraecola* and *Myzus persicae* 10% on orange and 5% on clementine.

Examination of the trees should be done in time, before the leaves start to curl. Of new leaves we check mainly the lower surface. The circulation of ants on the trees indicates that there are aphids, scale insects, or other insects producing honeydew.

When, in addition to the direct injury, we should limit the transmission of a virus to the trees, our intervention should be done as soon as the presence of the given aphid is detected, and the spray should be done very carefully so that the foliage is fully covered. The spray should be repeated as soon as the protective action of the insecticide expires.

In seed beds and on young trees in nurseries, but only there, granular formulations of long-residual-action systemic insecticides can be applied to the soil. On deciduous trees, in winter, to kill winter eggs of aphids and mites, such insecticides as winter spray oils alone or together with a synthetic organic insecticide can be applied.

***Aphis pomi* De Geer** *(Aphis mali, Doralis pomi)* **(Homoptera, Aphididae)**, comm. **apple aphid**

Adult. The apterous parthenogenetic viviparous female is 1.5-2.2 mm long and from green yellow to dark green (Fig. 39). The antennae

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are yellowish, the siphons black, cylindrical and narrower at the top. The cauda is from dark green to black, and as long as 1/2-1/3 of the siphons. The winged parthenogenetic viviparous female is 1.5-2 mm long (without the wings), and approximately 3.2 mm with the wings. The head and thorax are black and the abdomen green.

Host plants. Apple, pear, quince, species of *Crataegus,* and certain other fruit and ornamental Rosaceae.

Life history and damage. It is a non-migratory species. It overwinters mainly as a winter egg on the shoots and branches of apple and of the other host plants. From spring to autumn parthenogenetic generations follow one another. In late autumn sexual individuals are produced, and after mating the females lay the winter eggs. In addition to sucking sap, this aphid causes leaves to curl, and under exceptional cases fruit deformation.

Control. Mostly with systemic insecticides (see Aphididae).

Fig. 39. *Aphis pomi.* Wingless forms on tender apple leaves (photo S. Katerinis).

***Dysaphis plantaginea* (Passerini)** (*Anuraphis roseus*) **(Homoptera, Aphididae)**, comm. **pink apple aphid**

Adult. The apterous parthenogenetic viviparous female is 1.8-2.5 mm long and brown grey. It is covered with a fine waxy powder (Fig. 40). The siphons and the tip of the cauda are of dark color. The winged parthenogenetic viviparous female has dark brown to black head and thorax and a body length (without the wings) of 2-2.5 mm, and with the wings 3.8-4 mm.

Host plants. It is a migratory species. Primary hosts are apple and quince, and secondary the herbaceous *Plantago major* L.

Life history and damage. It completes many generations per year. It overwinters mainly as a winter egg between the scales of buds or near the buds of apple and quince. During the apple vegetative period,

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Figs 40-41. *Dysaphis plantaginea.* 40.Colony of the aphid and deformed apple leaves. 41.Wingless individuals on deformed apple codlings (photo B.I.K.).

generations of parthenogenetic individuals follow one another, and winged ones migrate to *Plantago* plants, where more than two pathenogenetic generations are completed. In autumn, winged males and winged thelytocous females return to the primary hosts (apple and quince). After mating, the females lay the winter eggs. This aphid stays on the lower leaf surface. In addition to removing plant sap, it causes leaf curl and deformation, and by injecting toxins it also deforms fruits to an extent that affects their normal development, or makes them unsuitable for the market (Fig. 41). It is considered a much more serious enemy of the apple than *Aphis pomi* with which it may co-exist on the same trees.

Control. When 1-2% of tips of shoots are infested, sprays with a systemic insecticide are recommended (see Aphididae).

Eriosoma lanigerum **(Hausmann) (Homoptera, Eriosomatidae)**, comm. **woolly apple aphid**

Adult. The apterous parthenogenetic female has a stout and oval body, 1.3-1.8 mm long, and according to some authors up to 2.8 mm. The antennae are short and there are no siphons. The color is dark purple, almost black, or dark brown. The body is covered with a whitish waxy secretion in the form of dust or filaments, that resembles cotton (Fig. 42). The wax filaments are reported to reach 3-4 mm in the spring and summer generations, while the waxy covering is not abundant in overwintering individuals. Winged individuals are generally light brown anteriorly and dark posteriorly (Balachowsky

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Figs. 42-45. *Eriosoma lanigerum.* 42-43.Colonies of the aphid on apple twigs (photo N.T. Papadopoulos and B.I.K. respectively). 44.Colonies on apple branches. 45.Deformed apple twigs with remnants of aphid colonies (photo B.I.K.).

and Mesnil 1935). Marchal (1928) gives detailed drawings of all stages and instars of this aphid, and photographs of tumors and lesions it causes to twigs and roots.

Host plants. In Europe and the Middle East it infests mainly apple (*Pyrus malus* and *P. malus* var. *paradisiaca*), which are the secondary hosts. It seldom occurs on quince, certain cultivars of pear, *Crataegus* sp., *Sorbus* sp. and *Cotoneaster* sp. (Marchal 1928), and does not cause them damage. In North America it has as a primary host the white or American elm, *Ulmus americana,* on which it deposits its winter eggs, and as secondary host the apple.

Life history and damage. For Greece 12-14 generations per year are reported by Isaakides (1936a), and the same by Balachowsky and Mesnil (1935) for Europe, and by Castellari (1966-1967) for the Emilia region of Italy, all developing parthenogenetically. In Italy, according to Della Beffa (1962), it overwinters as larva, but according to more

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Fig. 46. *Eriosoma lanuginosum.* Gall on elm twig (A.U.T.).

recent publications (Castellari 1966-1967), as apterous parthenogenetic adult female, in protected sites of the trunk and branches, or perhaps also in the soil on roots of apple. Referring to Europe, Balachowsky and Mesnil (1935) mention that it overwinters as virgin, apterous, not completely developed, i.e. as larva, on twigs, branches, or even on the trunk. In New South Wales, Australia, it is reported overwintering on apple mostly as larva (Asante et al. 1991). It infests shoots, branches, limbs, trunk, and roots up to a depth of approximately 25 cm (Figs. 43, 44). Both adults and larvae injure the tree. It pierces and sucks the tree sap. Its feeding causes proliferation (hyperplasia) of plant tissues which ends up in tumors and cracks of shoots (Fig. 45). In the cracks and cavities thus formed concentrate preferably the individuals of this aphid. In certain apple cultivars, in rare cases, it can enter the calyx and settle in the center of the fruit. Smaller tumors are caused in the roots. During the growing season generations follow one another. Certain individuals from shoots go to the roots and become rhizobious. Many generations are completed also on the roots. Dispersal from tree to tree is done with winged females which are formed in autumn. In Europe, in autumn, amphigonic individuals are also produced on apple, which give birth to sexual individuals and winter eggs. However, this occurs seldom, and in spring the fundatrices coming out of the winter eggs do not give progeny on apple. *E. lanigerum* is a serious pest of apple, because it weakens the tree, causing stunting and serious retardation of growth (Metcalf et al. 1951). It also may kill trees of susceptible cultivars. Certain cultivars such as the Firiki in Greece are relatively resistant.

Among the natural enemies of this aphid better known and effective is the parasitic hymenopteran *Aphelinus mali* (Haldeman) (Aphelinidae). It overwinters inside the body of the aphid.

Control. It is recommended to plant trees from uninfested nurseries, or to disinfest them before planting. Infested trees are sprayed with

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organophosphorous or carbamate aphidocides (see Aphididae) and in winter with winter spray oils combined with an organophosphorous insecticide. Good coverage is needed, to run off, of the whole tree and especially of the shoots and branches of it. In addition, the base of the trunk and the soil around it should be sprayed and followed by irrigation so that the spray liquid penetrates the soil to kill the rhizobious individuals.

Many countries, among which Greece, have introduced *Aphelinus mali* to biologically control the aphid. This hymenopteron is usually able to reduce to tolerable levels the population of its host in summer and autumn, but not in spring, as a rule.

Another aphid of the same genus, *Eriosoma lanuginosum* (Hertig) (Fig. 46) has species of *Ulmus* as primary hosts, and the pear and *Carpinus betulus* as secondary hosts. On pear trees it attacks the roots, especially the little ones, without causing serious injury, in Greece at least.

Aphanostigma piri **(Cholodkovsky and Mokrzecky) (***Phylloxera piri***) (Homoptera, Phylloxeridae)**, comm. **pear phylloxera**

It is a small apterous aphid, usually yellow or yellow-green and more seldom light brown. The adult parthenogenetic female, as well as the sexupara female are pear-shaped, 0.8-1 x 0.4 mm. The maximum width is in the mesothorax and the minimun in the posterior part of the body. The adult sexuales are smaller, with the sides of their body parallel. The length of the adult male is 0.35 and of the female 0.45 mm. The eggs of the parthenogenetic females are oval, yellow-green, 0.4 x 0.2 mm (Leclant 1963). The original description of its morphology was given by Cholodkovsky (1903). Data on morphology, life history, symptoms of injury to the tree, economic importance of damage it causes, and control measures are given by Swirski (1954), Leclant (1963), Swirski et al. (1969a,b,c, 1973), Geoffrion (1971) and others. Useful pictures of the insect and of symptoms of injury are given by Leclant (1963) and Geoffrion (1971) for France, and Swirski et al. (1969a,c) for Israel. Its only host is pear. It completes more than 3 generations per year. In regions of Italy and France with a climate approximating that of central northern Greece, it overwinters as a winter egg in cracks and fissures of the bark, or in other protected sites of the trunk and branches. In spring and summer it reproduces

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parthenogenetically. In autumn sexual forms appear and the female lays the winter egg. Larvae and adults are found on the trunk and branches, especially in fissures or other protected sites, where they pierce and suck the sap. In autumn when the population reaches its peak, colonies are easily detected also on exposed parts of the bark. In northern regions, when the colonies are on the bark, the injury to the tree is not substantial. However, when the insects settle in a suitable for them site of the fruit such as the calyx, their feeding causes necroses and favors infection by fungi that cause rotting. This makes the fruit unsuitable for the market. Cultivars with a concave calyx, such as Passe Crassane, are especially susceptible to injury. In France, pears that are bagged on the tree rot to a high percentage, whereas those exposed are infested less, and only in certain orchards and years. The insect was found in central northern Greece in an orchard of Passe Crassane pear trees. From necrotic spots of infested fruits from that orchard a fungus of the genus *Alternaria* was isolated (Tzanakakis 1976). In Israel the insect reproduces only parthenogenetically and overwinters in the buds (Swirski 1954). When populations are dense, colonies are observed even on exposed sites of the bark of the trunk, branches and twigs. In that country it causes bud necrosis and cracks of the bark that may kill twigs and branches. The cultivar Superfine suffers mainly bud necrosis, while the Spadona suffers necrosis of the bark of branches and fruit rot (Swirski et al. 1969c).

Certain authors believe that *Cicacium iakusuiense* Kishida (*C. iwakusuiense* Tabe and Mishima) which infests pear in East Asia in a similar way, is a different species from *A. piri.*

Control. In winter it is achieved with winter spray oils. In the warm season the most effective insecticide was, in Israel, diazinon, but also endosulfan and mecarbam were effective (Swirski et al. 1973). In cooler regions such as in Normandy, diazinon was not as effective as in Israel, azinphos-methyl and parathion-methyl having been affective. The need for good coverage of the whole tree is essential, because the insect settles preferably in protected sites of the bark and fruits. A mild volatility of the insecticide may be an advantage in certain climates and seasons (for details in Greek, see Tzanakakis 1976 and references therein, and 1980).

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Coccoidea (coccids, scale insects and mealybugs)

Most of them are of small size, the rest of medium size, with a variety of shapes and habits. Many species are serious enemies of plants, especially of trees and shrubs. In most Coccoidea there is strong sexual dimorphism. The adult females are apterous, in many species with a sac-like body, without a distinct separation into head, thorax and abdomen, without antennae, with atrophied legs or with small legs (Fig. 285). Those of the family Coccidae resemble plant galls (Fig. 347), and those of Diaspididae scales (Figs. 228, 284), while those of the Pseudococcidae (Fig. 247) and Margarodidae (Fig. 250) are covered with waxy secretions that resemble cotton or dust. The so-called waxy secretions of scale insects are mixtures of true waxes and other substances, including resins and lipids (Gullan and Kosztarab 1997). Their tarsi have only one article. The males have usually one pair of wings (despite being Homoptera), with a few veins, or are apterous. The males have atrophied mouth parts. The females are oviparous, ovoviviparous, of viviparous. They reproduce usually bisexually, but some species parthenogenetically. In one species, *Icerya purchasi* Maskell, hermaphroditic female-looking individuals are observed. The oocytes of the female of this species are fertilized by sperm of the same individual (autofertilization). The eggs of coccids are protected either inside an ovisac of xaxy filaments (Fig. 248), or under the maternal body (Fig. 347). In all scale insects, the larvae, at least during the first phase of the first stadium, have normal legs and can move by walking. A pronounced dispersal is observed during that young stage.

Many scale insects, except the Diaspididae, excrete honeydew which favors sooty mold fungi. For details on honeydew and the organs of scale insects that eliminate it, see Malumphy (1997). The honeydew constitutes food for certain species of ants, which take care of and protect their “cows” from natural enemies. The honeydew of scale insects constitutes food of other insects too, beneficial or harmful, such as the honeybee and the olive fruit fly, respectively. The direct injury to the plants is caused mainly by removing sap and injecting toxic substances contained in the saliva of certain species. Therefore, we have or may have weakening of the plant which sometimes may lead to death, necrosis of plant cells and tissues, development of sooty mold, soiling of the marketable fruits by the honeydew and sooty mold.

The scale insects have many natural enemies, mainly entomopha-

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gous (insectivorous) insects which reduce their populations. Most examples of biological control of insects using entomophagous insects come from the control of scale insects. The control of scale insects is usually achieved with chemical means, mostly contact insecticides such as mineral oils, organophosphorous, carbamate, or even lime sulfur. For desinfestation of young trees before they are planted and treatment of other plant propagation material in nurseries, fumigants are also used. However, the best strategy against most scale insects is integrated control (see Introduction).This strategy takes advantage of the natural enemies of scale insects and reduces the chances of population build up of other harmful insects and mites of fruit trees (see Aphids, above). The principal families of scale insects are the following.

Diaspididae (comm. **armored scale insects** or **scales)**

To this family belong many species of small size and characteristic shape. The adult females have rudimentary antennae and no legs. Their sac-like, often short and wide body is covered with a hard, waxy shield (scale, test, testa, aspidium) which resembles a scale or a small shell (Fig. 279). This scale of almost all armored scale insects is formed of secreted wax filaments, cemented by anal excretion, and embedded with the exuvia of the two preceding stages (references given by Gullan and Kosztarab 1997). The scale covers the body of the immobile (fixed) stages of these insects, i.e. from the second phase of the first larval stadium through the adult female (Figs. 47-58). From the egg (or the maternal body in the viviparous species) comes the neonate larva known as the “crawler”. It possesses developed thoracic legs, antennae with 5-6 articles, and eyes. It walks on the plant surface for a certain time, searching for a suitable site to settle. During this period the crawler can be carried away by wind to neighboring branches or trees, or may climb other insects or birds and thus be carried away to greater distances. When it finds the proper site, it introduces into the plant tissues its fiberlike sucking mouth parts and starts to suck sap. The larva possesses wax glands which open at the back of the abdomen. As soon as it starts to suck sap, the larva starts to secrete a waxy whitish protective cover. Under this cover it continues to secrete the waxy material and little by little, slowly turning its body around, it forms the scale. After the first ecdysis the larval exuvium is added to the outside of the new scale (Figs. 53, 54). The second-instar

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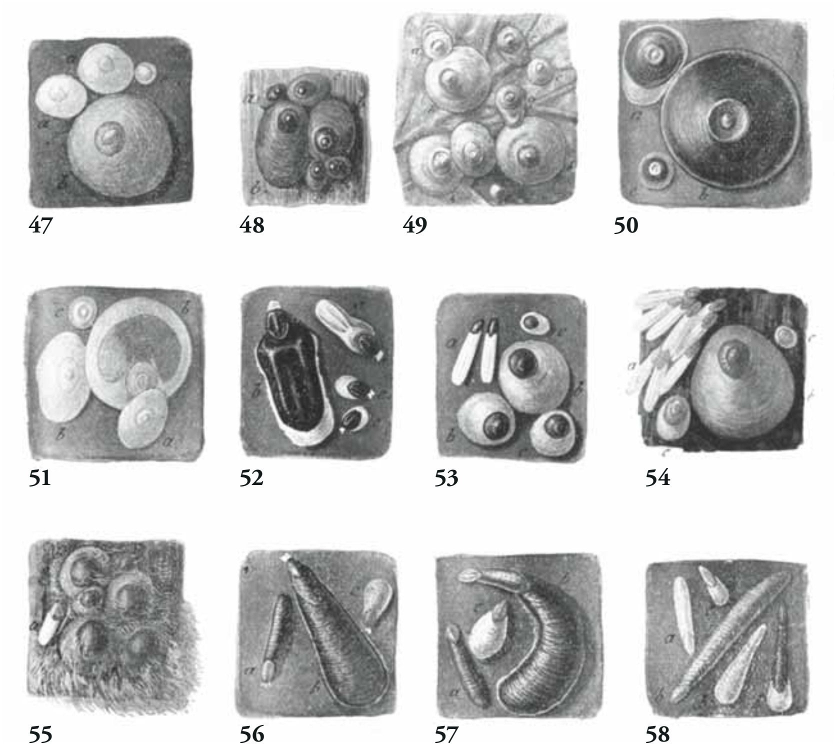

Figs. 47-58. Scales covering the body of larvae and female adults of species of Diaspididae drawn as seen with a simple lens, magnified by approximately 10 times. The long larval scales off the adult female scale are of male larvae. 47.*Aspidiotus nerii,* 48.*Targionia vitis*, 49.*Chrysomphalus dictyospermi,* 50.*Chysomphalus aonidum,* 51.*Aonidiella aurantii,* 52.*Parlatoria ziziphi,* 53.*Parlatoria oleae,* 54.*Pseudaulacaspis pentagona,* 55.*Epidiaspis pyricola,* 56.*Lepidosaphes pinnaeformis,* 57.*Lepidosaphes ulmi,* 58.*Leucaspis riccae* (R. Staz. Firenze).

larva has no legs and its antennae are rudimentary. It remains in the same place. It feeds and constructs its own scale which is larger than that of the fist-instar larva. With the second ecdysis, which is the last one, the adult is formed. The adult females remain in the same place, suck sap, construct their scale, mature sexually and lay eggs or, the viviparous ones, larvae. Their scale is much larger than that of the larvae. The larval exuvia are stuck near the center of the adult scale. There are species where the larval scales are located off the center of the adult one, for example those of the genus *Lepidosaphes,* known

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as oyster scales (Figs. 56, 57). In those species the larval scales are very close to the anterior end of the adult scale. The male larva has more instars than the female one. After the second ecdysis the male larva stops eating and, under the scale, undergoes one more ecdysis-metamorphosis and becomes pupa, with evident the characteristics of the adult (compound eyes, antennae, wings, copulatory organ). In other words, the male of Diaspididae resembles in its development the holometabolous insects. When the pupal stage is completed, the adult male comes out of the larval scale. It does not have mouthparts and lives only a few days. Usually it flies and mates at night. In certain species the male larvae tend to settle in sites of the tree different from those of female larvae. This causes the formation of colonies of larvae of one sex (Fig. 154). The scale of females (adult and larva) has various shapes and dimensions, depending on the species. It is round, ellipsoid, oval, mussel-shaped, or other. The scale of male larvae is usually oblong. In many species the immobile stages secrete a fine waxy membrane on the ventral side of their body. This ventral membrane is a continuation of the scale. Thus, the insect's body does not come in direct contact with the plant surface, except for the mouth parts.

The saliva of certain species is toxic to the plants, causing chlorotic spots or deformations around the point where the insect's mouth parts are in. Certain species may kill entire branches or even trees. More often, the presence of scales of certain species on the marketable produce is sufficient to lower, little or much, its commercial value. Diaspididae do not produce honeydew and, therefore, do not favor sooty mold.

The populations of Diaspididae are often held in check by various natural enemies, mainly parasitic Hymenoptera and predatory insects. Chemical control is effective mainly in the early part of the first larval stadium, when the larval body is not yet protected by the scale. If the period of hatching of the larvae of a given generation lasts long, two insecticidal applications are usually needed (one against the earliest larvae and one against the latest ones). Complete and careful coverage of the whole tree with the spray liquid is necessary. Organophosphorous and carbamate insecticides alone, or combined with a sray oil are effective against the scale insects, but reduce or even eliminate beneficial insectivorous insects. On deciduous trees, especially against scale insects that are difficult to control, and their extermination from an orchard is urgent, such as the San Jose scale

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Quadraspidiotus perniciosus, winter sprays are also recommended with a spray oil fortified with an organophosphorous insecticide.

Coccidae (Lecaniidae)

The shape of the body varies with the species. Generally, the segments of the female body are not obvious. The body of many species is much convex, approximately hemispherical in the adult female, and little convex in larvae (Figs. 156, 347). The exosceleton of certain species is covered by a thick waxy layer, which in the adult females is often quite hard. The degree of development of legs and antennae differs from species to species and depends on whether a given species changes places during its life. In many species the larvae have developed legs and antennae and can move, as do the adults of certain species. The Coccidae complete a few generations per year, usually 1 to 4. Many species produce abundant honeydew which soils the foliage and fruit of host plants and favors the development of sooty mold fungi.

Pseudococcidae (comm. **mealybugs)**

The females have a soft, sac-like, usually oval body, with distinct segments, which is covered with flour-like or fiber-like waxy secretions (Figs. 244, 247). These secretions which are mainly protective, often extend beyond the perimeter of the body. All stages (larvae and adult) have legs and can walk. The mealybugs are favored by high air humidity and relatively high temperature. This is why they develop well especially in greenhouses and other humid sites, and in trees and shrubs with dense foliage. They produce abundant honeydew and thus soil the foliage and fruits and favor sooty mold. They are often held in check sufficiently by natural enemies, such as predatory Coleoptera Coccinellidae, Neuroptera, Diptera Syrphidae and parasitic Hymenoptera, when ants do not impede the action of those natural enemies. When the action of natural enemies is limited, as is the case in many orchards, chemical control is recommended (see *Planococcus citri*).

Margarodidae

In the females the somatic segments are rather distinct. The

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body is soft and in many species covered with waxy secretions. For the composition of the waxy secretions of softscale insects see Tamaki (1997). The legs and antennae are usually well developed in both adults and larvae. The males are winged, with long antennae of 10 segments. Two species are of interest to Greece: *Marchalina hellenica* which abounds on certain species of pine trees (Fig. 418). The honeydew it produces is an important food of honeybees (it is the source of pine honey). *Icerya purchasi,* the second species, infests citrus trees and certain ornamental plants (Figs. 248-250).

Quadraspidiotus perniciosus **(Comstock)** (*Aspidiotus perniciosus, Diaspidiotus perniciosus*) **(Homoptera, Diaspididae)**, comm. **San Jose scale**

Adult. The adult female has a scale which is approximately circular, a little convex, grey, with yellowich larval exuvia at its center and an approximate diameter of 2 mm (Fig. 59). Under the scale the female body is yellow or almost orange, and approximately 1 mm. The male is winged, orange, or yellow.

Larva. The scales of larvae are darker than those of adult females. Those of female larvae are approximately circular, and of male larvae oblong oval.

Host plants. It is polyphagous. It infests at least 200 species of plants, especially trees and shrubs. It infests all deciduous fruit trees, and is a serious enemy of stone fruit and pome fruit trees.

Life history and damage. In northern Greece it completes 3 generations per year on peach (Paloukis 1979) and also 3 on almond (P. Katsoyannos and Argyriou 1985). In certain valleys and relatively warm areas a partial 4th generation was observed in certain years (Kyparissoudas 1987b). It overwinters as a larva or adult female, under its scale on branches and twigs of trees. On peach trees of northern Greece it overwinters mostly as a first-instar larva (not crawler) and less so as a second-instar larva or adult female. The first instars (L1) which have overwintered become active, feed and develop from late March to early April. They become second instars (L2) in March-April, and adult from mid-April to mid-June. The female, which is viviparous, lays for weeks, often more than six. The neonate larvae (crawlers) of the first generation are seen on peach trees in May-June, the settled (immobile) L1 in mid-May to mid-July, the L2 from

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Figs. 59-61. *Quadraspidiotus perniciosus.* 59.Preimaginal stages and adults on twig of *Prunus* sp. (A.U.T.). 60.Spotting of an apple at the sites where the scale insect had settled, and scales of preimaginal stages and adults in the calyx cavity (photo U. Remund). 61.Infestation and spotting of a pear (A.U.T.).

mid-June throughout July, and the adults in July to mid-August. The second-generation crawlers occur from mid-July to mid-September, the settled L1 in August-September, the L2 from mid-August to late September, and the adults in September-October. The population peaks of crawlers, which is the best time to apply insecticides, occur in late May to mid-June (of the first generation), in August (second generation), and mid-October to early November (third generation) (Paloukis 1979). Depending on the area and the year, the start, maximum and end of the crawler population of each generation may differ from the above average values, as concluded from captures on sticky bands on peach trees of two areas in central northern Greece (Kyparissoudas 1987b). The species and the cultivar of the fruit tree, and possibly also its age and cultural conditions in the orchard play some role on the period of appearance of crawlers.

Q. perniciosus spreads from tree to tree with birds and insects on which the crawlers climb, but also by wind which takes away crawlers. This scale insect infests shoots, twigs, branches of any age and diameter, trunk and fruit. On leaves it settles mainly when its population on branches and twigs is very dense. The crawlers which

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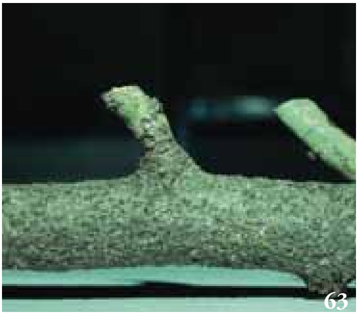

Figs. 62-63. *Quadraspidiotus perniciosus.* 62.Apple trees, at summer, mostly dead because of infestation by this scale insect (photo R. Isler). 63.A dense population of the insect on the bark of an almond twig (photo B.I.K.).

then go to leaves are mostly male ones. Where the insect's mouth parts are inserted, red or reddish spots are caused in the cambium of twigs and branches, and red spots and concave points on leaves (Fig. 59). When settling on fruits occurs early, when they are small, deformation and limited growth are caused. The spots when many, affect the commercial value of fruits, especially of apples and of late-cultivar pears, which are infested more and become unsuitable for the fresh-fruit market (Figs. 60, 61). However, such fruits can be used by the canning industry. On plums small protuberances are caused. Cherries, apricots and early peaches usually escape injury, because they are harvested early, while late peaches are injured, but not much (Paloukis 1979). In addition to fruits, the San Jose Scale may cause, and often causes, serious injury to the tree. It can kill branches by killing their bark, and subsequently kill the whole tree (Fig. 62). In heavily infested trees, the whole bark is covered with the grey overlapping scales of the insect (Fig. 63). *Q. perniciosus* is considered as one of the most destructive scale insects internationally, because it injures the fruit, reduces the yield, kills trees and is not controlled easily. Many countries forbid the introduction of plant parts or plant products infested by this insect.

Control. It is difficult. At all seasons, complete and careful coverage of the whole tree with the spray liquid is essential. One winter spray and two or more during the growing season are necessary. The winter spray is carried out from leaf fall till the end of winter, before the buds of the trees swell. A winter oil with dinitrocresol, or plain dinitrophenol

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products (DNOC, dinoseb, and others), or an oil with a suitable organophosphorous insecticide, such as carbophenothion, diazinon, ethion, or parathion used to be effective, when and where permitted. Winter oils should be avoided on peach trees. The winter spray aims at reducing the overwintering insect population substantially, so that the summer sprays be more effective. Also, the winter spray kills the winter eggs of aphids and mites, and on stone fruit trees reduces considerably the overwintering larvae of the moth *Anarsia lineatella* and less so of *Grapholitha molesta.* If the winter insecticidal spray is combined with Bordeaux mixture, the concentration of the winter oil should be slightly increased. In the Francophonous Switzerland, on pome trees, Charmillot et al. (1997a) recommend one spray with mineral oil when the buds begin to develop (beginning of new growth). At that time fenoxycarb is also effective. In very heavily infested trees, one or two more sprays with an organophosphorous insecticide are recommended in June.

Irrespective of the area, the sprays during the growing season are carried out when the insect is at the crawler stage, and especially at that of the first generation. As the crawlers appear usually a certain period after the capture of the first adult males in pheromone traps (Fig. 64), the appearance of adult males is being monitored, and

Figs. 64-65. *Quadraspidiotus perniciosus.* 64.Pheromone trap to capture adults (photo B.I.K.). 65.Rearing of the insect on pumpkin, to produce its parasitoid *Prospaltella (Encarsia) perniciosi,* for biological control (photo B.I.K.).

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subsequently the appearance of crawlers is followed with sticky bands placed around branches. Because in each generation crawler hatching lasts usually for more than a month, it is wise to carry out two sprays, 10-20 days apart, so as to kill most of the crawlers (Paloukis 1979).

Following up and recording the adult males caught in pheromone traps is easier than recording the crawlers caught on sticky bands. In apple orchards of the areas of Naoussa and Macrohori Imathias, Kyparissoudas (1990a) found that there is a close correlation between the time of first captures in pheromone traps of adult males of the overwintered generation, and the time of appearance of the first crawlers of the following (first) generation. Male adult captures started in the second half of April and crawler captures on sticky bands a month later. The peak of crawlers was observed 12 days after the beginning of crawler captures. On the basis of those data, Kyparissoudas obtained a satisfactory control of this insect, and a minimum of apple infestation with one spray with quinalphos 33 days after the capture of the first males in pheromone traps, and a second spray 10 days later. The second spray approximately coincided with the peak of crawlers. Applying only one of those two sprays gave less satisfactory control. Against crawlers other insecticides have also proved satisfactory, such as azinphosmethyl, diazinon, dimethoate, fenthion, mecarbam, methidathion, parathion, and phosphamidon.

The Plant Protection Forecasting Services advise the fruit growers regarding the proper periods for spraying. In heavily infested orchards and more so in orchards where the insect is first detected in an area, killing the heavily infested trees with fire or other means, and careful control on the rest of the trees is recommended. It is thus hoped to limit or delay the spread of this insect which has continued since it first entered Greece in 1968 (Paloukis 1968). In setting new orchards, planting of uninfested trees is essential.

In many countries including Greece attempts at biological control of the San Jose Scale have been made by releasing the parasitic hymenopteron *Encarsia (Prospaltella) perniciosi* Tower (Fig. 65), and other entomophagous insects, such as the predatory coleopteran *Cybocephalus fodori* Endrody-Younga (Argyriou 1981, P. Katsoyannos and Argyriou 1985).

***Stephanitis pyri* (F.)** *(Tingis pyri)* **(Hemiptera, Tingidae)**, comm. **pear lace bug**

Adult. The body is flat, 3-4 mm long and 2 mm wide, with

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characteristic lace-like light-colored hemihelytra (forewings), each of which bears two large brown spots. The body is brown or almost black. The prothorax has one dorsal and two lateral semicircular lace-like extensions (Fig. 66).

Egg. White, oblong, slightly curved at one end, of an average length 0.38 mm (Kattoulas and Papanicolaou 1967). It is almost entirely inserted in the leaf. The end prodruding from the leaf surface is covered with a dark secretion by the female. The eggs are laid close to one another, from a few to a hundred (Silvestri 1939).

Larva. On the head, the sides of the body, and along the dorsal part of the body the larva has spine-like protrusions. It is greenish or yellowish, with vertical dark stripes on the anterior part of the abdomen and near the middle of the abdomen, as well as at the base of the developing forewings.

Host plants. Mainly pome trees (apple, pear, quince), and less so other trees and shrubs (plum, cherry, peach, pyracantha, rose, hazelnut, mulberry).

Life history and damage. It is reported to complete 3 and more rarely 4 generations per year (Isaakides 1936a, Kattoulas and Papanicolaou 1967). It overwinters in the adult stage in fissures of the trunk, on the soil surface, especially if covered with dead leaves, or in other protected sites of the orchard. During the active season it usually lives in groups on the underside of leaves. The female inserts its eggs in the leaf parenchyma and covers each oviposition site with a dark secretion (Fig. 67). Larvae and adults pierce and suck the leaves, which become chlorotic and have a characteristic appearance, with many yellowish specks on their upper surface (Fig. 68). The under surface of leaves has abundant black specks, exuvia, and live larvae and adults. The oviposition holes also contribute to the leaf injury (Silvestri 1939). When infestation is heavy, the leaves fall and fruit production is adversely affected. However, this insect rarely causes serious damage. In southern Italy 3 generations per year are reported by Silvestri (1939). In that region, the adults that overwintered were seen on the new foliage from early May on. The second generation occurred in June-July. The preimaginal stages of the third generation occurred in August-September and its adults overwintered. Predatory Anthocoridae and Chrysopidae in southern Italy made damage to pome trees occasional. In France predatory insects and a Thysanopteran also seemed to be effective against *S.*

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Figs. 66-68. *Stephanitis pyri.*
66.Adult (photo N.T. Papadopoulos).
67.Undersurface of a pear leaf with adults, larvae, eggs, and feces of the insect.
68.Infestation of pear leaves, as seen on the upper side (photo B.I.K.).

Control. If necessary, control is similar to that against aphids, using organophosphorous or other insecticides, preferably systemic, alone or combined with 1% mineral oil (see Aphididae). The insecticidal sprays against the codling moth usually also limit the populations of *S. pyri.*

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Calocoris fulvomaculatus De Geer, (Hemiptera, Miridae)

Anagnostopoulos (1939) mentions that adults and larvae of this species pierce and suck the flesh of young fruits of apple and pear. The feeding punctures develop into characteristic depressions and hardening of developed fruits, and contribute to lowering their market value. Some growers call “lithiassis” the hard spots of pears. Older authors mention that infestation by this bug may deform young fruits considerably and even cause them to fall. In view of great morphological similarities between certain species of this genus, reservations about the species identity are justified. Insecticides applied in spring against major pests of the trees have limited in recent years the importance of this insect as a pest of apple and pear. Pegazzano (1958) mentions that probably *Calocoris norvegicus* caused stony pears in Italy.

Weevils

There are two groups of weevils infesting fruit trees and grapevine (Figs. 69-71). One group belongs to the beetle family Attelabidae and the other to the Curculionidae. They all have a rostrum. The Attelabidae have a very long and slender rostrum without lateral grooves. Their clublike antenae are not elbowed. Their general color is usually metallic, shiny. The elytra are distinctly wider than the pronotum and do not cover the tip of the abdomen (Figs. 72, 161). They have one generation per year, or one in two years. They overwinter as a rule in the soil in a cell, or in other protected sites. The adults eat buds, flowers, fruits, leaves, or tender shoots. The erosions they cause have the form of hollows or of deeper holes, which in some species reach the endocarp (Figs. 71, 299A). They oviposit inside fruits and, some species, in tender shoots, after having bored with their rostrum an oviposition hole. In species that oviposit inside fruits the larva eats the seed. In some species the adult carries fungi of the genous *Sclerotinia (Monilinia)* which cause rotting or mummification of the fruits (Balachowsky and Hoffmann 1963). Many species belong to the genus *Rhynchites.* The adult weevils are susceptible to most organic synthetic contact insecticides.

The other group of weevils infesting fruit trees belongs to the beetle family Curculionidae and the genus *Anthonomus.* The adult head is also extended to a rostrum at the tip of which are the mouth parts (Figs. 73, 74). The antennae are clublike and elbowed. They

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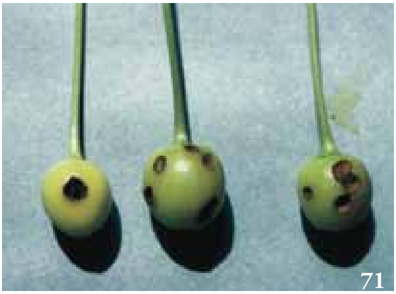

Figs.69-71. Erosions caused by adult weevils to: 69 apple, 70 very young apples, 71 sour cherries (photo B.I.K.).

are located on the rostrum which is slender, cylindrical and has a groove along each side. The surface of the body is usually drab and its color resembles that of the bark of the host-tree. With its rostrum the female bores an oviposition hole in closed flowers, in mixed buds or in leaf buds, and introduces an egg in each hole. The larvae are apodous (legless), white or yellowish, with a brown head (Figs. 75, 76). The *Anthonomus* weevils have one generation per year. They infest pome and stone fruit trees. The species that oviposit in flower buds, spend the summer, autumn and winter in the adult stage. The larvae of certain species develop inside closed flowers, which do not open because of the injury caused. Those of other species develop inside buds which also do not develop because of the injury caused (Fig. 76). Pupation occurs inside the infested plant organ. These weevils are controlled with organic synthetic contact insecticides, directed against the adults, before they oviposit.

Rhynchites bacchus **L. (Coleoptera, Attelabidae)**, comm. **pome and stone fruit weevil**

Adult. It is 4.5-6.5 mm long (Balachowsky and Hoffmann 1963). The body is red or copper-red metallic, and the antennae and part of the rostrum black. The pronotum and the elytra are dotted and covered with fine hairs (Fig. 72).

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Fig. 72 . *Rhynchites bacchus* adult (photo B.I.K.).

Larva. The fully grown larva is 5.5-6.5 x 3-3.2 mm. and whitish.

Host plants. Pear, apple, apricot, cherry, plum, almond, and other Rosaceae.

Life history and damage. It completes one generation per year, or one in two years. In the first case it overwinters as adult under dry bark, in the soil, or in other shelters. In the second case (i.e. of semivoltinism) it spends the first winter as a grown larva in the soil, in a cell that it itself forms, and the second winter as an adult. The adults come out of their winter shelters usually in April, and in certain areas later. They eat buds, bark of new shoots, and later young fruits, causing characteristic feeding holes (Figs. 67-71). After having matured reproductively and mated, the female inserts its eggs, one by one, in holes it has bored with its rostrum in young fruits. After each oviposition it plugs the opening of the oviposition hole with a secretion, and severs partially the pedicel of the oviposited fruit so that it withers. The larva feeds on the flesh of the fruit, where it bores a gallery. When it completes development it abandons the fruit, drops to the soil, and forms a cell at a small depth where it remains for a few months or for more than a year, before it pupates. A percentage of the infested fruits drops to the soil before the larvae abandon them. The adults are formed in late summer or in autumn. They come out of the soil and destroy buds by devouring their inner part. After that feeding period they go to their overwintering sites.

The adults destroy buds in spring, summer and autumn, and fruits in spring and summer by their feeding punctures. The larvae also destroy fruits in spring and summer. Fruits with oviposition holes are infected almost always by the brown rot fungi (Balachowsky and Hoffmann 1963). In Greece, damage by this weevil is usually not

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serious.

Control. In autumn and spring, as soon as a considerable number of adults or of feeding punctures (holes) in buds or young fruits is detected, a timely application of a contact insecticide is recommended. If the trees are few and we want to avoid the use of insecticides, we can shake the trees in early morning hours and collect the adult weevils and infested young fruits in a suitable cloth spread under the trees.

There are some more species of fruit-infesting weevils the life history of which is not given in the present book. Among them *Rhynchites aequatus* was observed on pome and stone fruits, *R. aereipennis* on apple, *R. lenaeus* on pear, *R. pauxillus* on apple and pear, *R. smyrnensis* on apple and stone fruits, and *R. versicolor* on pear (Balachowsky and Hoffmann 1963).

***Anthonomus pomorum* L. (Coleoptera, Curculionidae)**, comm. **apple blossom weevil**

Adult. With the rostrum it is 5 mm long, and without it 3 mm (R. Stazione Firenze 1924). The general color is dark brown. The rostrum, the antennae and the legs are reddish. The pronotum has 4 brown spots and each elytron in the middle of its length an oblique dark grey stripe and further back another narrower vertical also dark stripe (Figs. 73, 74). The elytra have hollows along longitudinal lines. The anterior femora have each a spine-like tooth as long as the width of the femur.

Larva. It is apodous, whitish or yellowish, with a dark brown head and a final length of 6 mm (Fig. 75).

Host plants. Apple, pear, and wild pear *(Pyrus amygdaliformis).*

Life history and damage. It has one generation per year. It overwinters as adult in fissures of the bark, and other protected sites of the host tree. It becomes active in spring, before the host trees bloom. After feeding, maturing sexually and mating, the female opens with its rostrum a hole in a closed flower and deposits an egg inside. The larva consumes the stamens and the pistil. In approximately 3 weeks it completes its growth and pupates inside the flower (Fig. 75). The corolla of infested flowers does not open. It dries out, becomes brown and somewhat resembles a clove (nail of clove) (Fig. 76). Approximately 10-15 days after pupation the adult comes out of the flower. After feeding on the foliage for a few days it remains in

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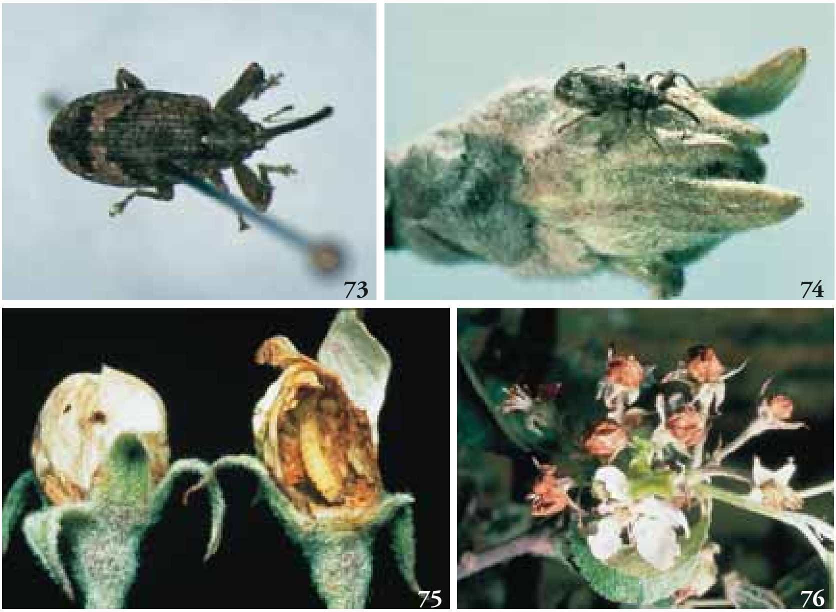

Figs. 73-76. *Anthonomus pomorum.* 73.Adult (photo B.I.K.). 74.Adult on a developing bud. 75.Larva in an infested flower bud (photo A. Staub). 76.Infested apple flower buds which have not opened (photo H. Hoepli).

dormancy in shelters in the orchard throughout the summer, autumn and winter (Isaakides 1936a, Chevalier and Grison 1963). When this insect's population is not dense, it causes no economic damage. It simply destroys a percentage of the flowers, thus contributing to a thinning of the usually abundant fruit load. However, when the insect population density is high, damage may be serious.

Control. One spray with an organic synthetic insecticide when the adults come out of their overwintering quarters is generally sufficient for protecting the fruit. Most suitable times for spraying are the "green tip" and "pink bud" stages of development of the host tree. If cold weather delays bud development, a second spray may be needed one or two weeks later.

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***Anthonomus pyri* Kollar** *(A. cinctus)* **(Coleoptera, Curculionidae)**, comm. **pear bud weevil, pear anthonomus**

Adult. It is rust-brown, and 4-5 mm long (Fig. 77). At the base of each elytron on the 3rd interstria there is a velutinous protruding curvature (Balachowsky and Mesnil 1935). Its host is the pear tree. Only exceptionally it has been recorded also on apple in the Netherlands and England.

Life history and damage. It has one generation per year, and a seasonal history similar to that of *A. amygdali* on almond (see insects of stonefruit trees). Adults are formed in May. After feeding on pear foliage, the reproductively immature females remain dormant from June to September. They become active in autumn, feed on buds, mature sexually and in late autumn and winter oviposit inside the mixed buds of pear. The larvae develop in winter and spring in the buds. Infested buds do not develop (Chevalier and Grison 1963). The sprays against the codling moth usually limit this weevil satisfactorily. If need be, a spray in late September with an organic contact insecticide against the adults, before they oviposit, will suffice.


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Fig. 77. *Anthonomus pyri* adult (photo B.I.K.).

Another species, *A. spilotus* Redtenbacher, much resembling *A. pomorum,* infests pear and *Mespilus germanica.* It is 3-3.6 mm long, also univoltine, and overwinters as adult. According to Balachowsky (1963), the overwintered adults appear on pear trees in the Montpellier region of France in mid-March. Their feeding on buds causes an interior necrosis then blackening. They oviposit until May. Early ovipositions, before buds develop, are inside buds. The ordinary laying is on the young leaves of pear before their lamina is completely unrolled. The larvae feed and develop inside the rolled foliar lamina. The leaf blackens and does not fully spread. Pupation takes place in the rolled leaf.

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Fig. 78. *Apiomyia bergenstammi.* Tumor of a pear shoot caused by the development of a group of larvae inside it (photo N.T. Papadopoulos).

Apiomyia bergenstammi **Wachtl (Diptera, Cecidomyiidae)**, comm. **pear bud midge**

Adult. It is black and 2.8 mm long (Anagnostopoulos 1939), or brown with red abdomen and 3-4 mm long (Della Beffa 1961).

Egg. Red.

Larva. Yellowish or orange, and 3.5 mm long, when fully grown.

Host plants. Pear, and wild pear *(Pyrus amygdaliformis).*

Life history and damage. It completes probably one generation per year. It overwinters as a developed larva inside the tumors that groups of larvae have caused on the twigs of pear (Fig. 78). It pupates in early spring. The adults emerge in spring, usually in late March, and deposit their eggs in groups on buds before the latter develop. According to Anagnostopoulos (1939) they select buds distal to older tumors, and according to Della Beffa (1961) also on buds at the base of young shoots. The larvae enter the bud where they cause the formation of a gall inside which they develop. The gall is an approximately round tumor with nipple-like extensions, each of which corresponds to a larval cell (Fig. 78). Each larva lives and feeds in its own cell.

Usually, this insect does not cause considerable damage to the pear tree, because its population is limited by parasitic hymenoptera. If needed, control consists in timely removal and destruction of the twigs that bear galls.

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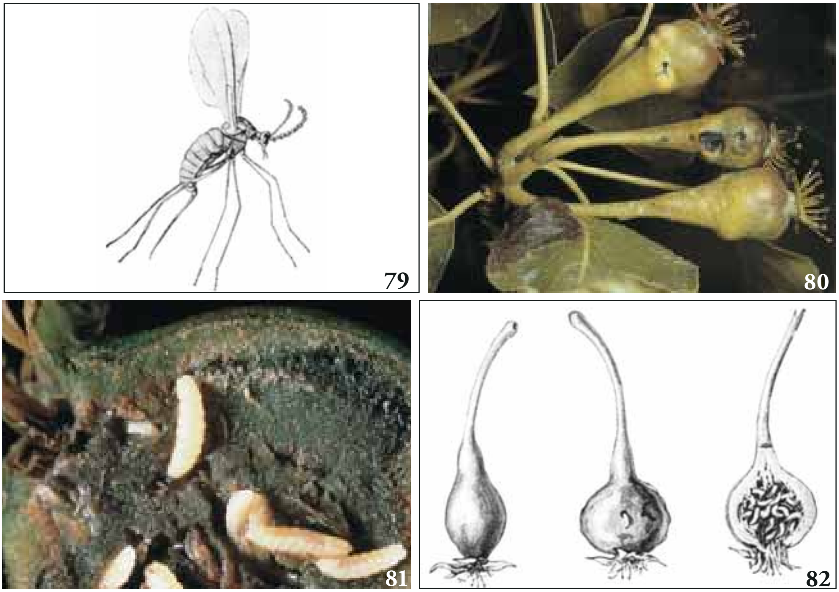
Contarinia pyrivora **(Riley)** *(Diplosis pyrivora)* **(Diptera, Cecidomyiidae)**, comm. **small pears midge**

Adult. The adult male is 2-3 mm and the female 3-4 mm long, with slender and long legs. It looks somewhat like a mosquito, as most midges do (Fig. 79). The head is black, and the antennae brown or almost black, hairy, with 26 articles. The thorax is black or black-grey with slightly silvery reflections. The wings have three longitudinal veins, the anal one being bifurcate. The abdomen is brownish and the legs brown, with fine white hairs. The male genitalia are forceps-like. In the female they consist of an extendable slender ovipositor which, during oviposition surpasses in length the length of the female body (Balachowsky and Mesnil 1935).

Egg. White or yellowish, transparent, with a slender stalk for adhering to plant tissues.



Figs. 79-82. *Contarinia pyrivora.* 79.Adult (Sta. Firenze). 80.Infested pear fruitlets (photo R. Rohner). 81.Fully grown larvae inside a pear (photo U. Remund). 82.Left healthy pear fruitlet, center infested one with grown larva abandoning it, right fruitlet cut open to show grown larvae inside it (natural size) (Sta. Firenze, from Marchal).

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Larva. At first almost transparent, hard to see. Later it becomes white or yellowish. It is long, narrower at the two ends, and of a final length of 2.5-3.5 mm. The fully grown larva is light yellow or light brown (Fig. 81). Same as in other species of the same family, the larvae have on the ventral side a narrow, dark, sclerotized plate, the sternal spatula.

Host plant. Pear.

Life history and damage. It has one generation per year. It overwinters as a pupa in a cocoon in the soil. It becomes adult in spring, when the new growth of the pear tree starts, and inflorescences have not yet developed. The females oviposit when the flowers have spread on the corymb but before they open. The female then introduces its long ovipositor between two petals and deposits 12-15 eggs (according to some authors up to 30) inside each flower. The eggs are laid on anthers, the pistil, or the interior of the corolla. More than one female may oviposit in the same flower. The young larvae hatch in a few days. They descend and enter the ovary of which they consume the interior. Their presence in the flower causes a hyperplasia and deformation of the flower base, which swells and becomes bigger than that of uninfested flowers. At approximately the end of the blooming period of pear trees, the infested fruitlets are definitely bigger than the unisfested ones, and often deformed (Fig. 80). Later, from mid-May on, the healthy pears continue their growth and surpass the size of the infested ones, the latter stopping to grow. In early May the larvae complete their growth (Fig. 82) and, one by one, abandon the infested fruitlet from a crack or hole on the side and less often from the calyx cavity and with a sudden movement they jump to the ground. They enter the soil at a depth of 8-10 cm, spin a cocoon, pupate, and remain there throughout the winter. Certain infested fruitlets drop before the larvae abandon them, whereas the rest drop from the tree later.

This insect has natural enemies wich often limit its populations to acceptable levels. Among them are the parasitic hymenopterans *Inostema pyricola* Kieffer, *Platygaster lineatus* Kieffer, *Tridymus pyricola* Marchal, and *Chasmodon apterus* Vees (Balachowsky and Mesnil 1935).

Control. Timely collection from the trees and the soil surface and destruction or deep burial of the infested fruitlets, as soon as they can be distinguished from the healthy ones, and before the larvae abandon them. According to Anagnostopoulos (1939) this should be

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done in the Peloponessus before May. A light superficial ploughing under the tree canopy in June-July exposes the cocoons to the sun and contributes considerably to population reduction (Tremblay 1991). In areas where serious damage is frequent, one or two sprays with an organic contact insecticide are recommended when the closed flowers have swollen, but before they open.

***Dasyneura pyri* Bouché (Diptera, Cecidomyiidae)**, comm. **pear leaf midge**

Adult. It is brown-black or reddish, with black eyes, and antennae with 15 articles (Fig. 83). On the dorsum it has 4 lines of yellow hairs and its abdomen is striped. It resembles somewhat *Contarinia pyrivora* (see above), but is smaller (1.5 mm long) and usually of a lighter color.

Egg. White, with a reddish hue, and 0.3-0.4 mm long (Tremblay 1991).

Larva. The second instar larva is yellowish. The fully grown one (third instar) is yellowish or whitish and on an average 1.6 x 0.6-0.7 mm.

Host tree. Pear.

Life history and damage. It overwinters as a fully grown larva, in a cocoon in the soil. Anagnostopoulos (1939) reports 2 generations per year in Greece. The adults of the second generation (the overwintering one) come out of the soil in mid-April and lay their eggs, usually in

Figs. 83-84. *Dasyneura pyri.* 83.Adult (photo A. Staub). 84.Rolled pear leaves infested by larvae (photo B.I.K.).

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groups, on the upper surface of the tips or of the axillae of the very young, still rolled, not fully expanded pear leaves. The larvae remain hidden on the upper leaf surface, near the perimeter, of young leaves where they feed on the surface layers of the parenchyma. The presence of the larvae causes hyperplasia of the leaf blade which becomes thicker, deformed, and does not fully expand sidewise, thus creating on one or on both sides of the mid-vein a little tube, in which the larvae protected develop (Fig. 84). This typical rolling of the leaves may also make then wavy. When they complete growth, the larvae drop to the ground where they pupate at a small depth. The infested leaves at first do not change color. Later their perimeter becomes red, and after the larvae have abandoned them they have cracks, become dry, black, and some of them drop. If we unroll infested leaves early, when they are still green, we will find inside each rolled gall 15 larvae on the average (Balachowsky and Mesnil 1935). According to Anagnostopoulos (1939) the first spring generation used to cause little injury of no economic importance, while the second (summer) one even less so. In the Halkidiki area of coastal northern Greece, on trees that were irrigated frequently, destruction of most tender leaves, especially of suckers, or of shoots with vertical direction and quick growth had occurred, while on the same trees, ripe leaves of shorter non vertical shoots of the same season were virtually uninfested. In the infested leaves the larvae in late April were almost fully grown (M.E.T. unpublished data).

Control. Usually no control measures are needed against this midge. The timely cutting off and destruction of rolled leaves, before the larvae complete growth, is not practical unless applied to only a few trees. In case of heavy infestation of young trees, certain authors recommend one or two insecticidal sprays. Tremblay (1991) recommends against the young larvae, a spray after full bloom with a systemic organophosphorous insecticide with short residual action, such as heptenophos.

Another related midge, *Dasyneura mali,* infests in a similar manner the tender leaves of apple in Italy and Switzerland (Fig. 85).

Leaf miners

They are the smallest moths infesting fruit trees. The adults are 2.5-4 mm long and the fully grown larvae 4-9 mm. Their small size allows a larva to complete development in only a part of an apple

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Fig. 85. *Dasyneura mali.* Rolled young apple leaf which contains larvae (photo A. Staub).

or pear leaf, and there are cases where a single leaf may house 3-5 or even more larvae which all develop normally, each in its own gallery. The adult female deposits its eggs one by one on the surface of leaves. The neonate larva enters the leaf, where it bores a gallery, feeding on the leaf parenchyma. The shape and external appearance of the gallery differ from species to species of leaf miner. The galleries of certain species are so characteristic that they suffice for us to know the identity of the species that made them. However, the characteristics of the gallery may be affected by the species and cultivar of the tree, the age of the leaf, the location of the gallery in the leaf, and the generation of the insect. For example, the galleries of the overwintering generation may differ from those of the spring or summer generations of the insect.

The leaf miners of pome trees are oligophagous or polyphagous, and multivoltine. The extent of damage they cause depends on the number of galleries per leaf. One or a few galleries per leaf usually do not reduce the photosynthetic capacity of a tree to a degree that requires control measures. However, when the galleries per leaf are many (Fig. 91), damage may be serious, because of substantial reduction of the active leaf surface.

The best strategy to control leaf miners of pome trees is the integrated one, because for most of those leaf miners there are effective natural enemies (parasitoids), at least in certain seasons of the year. Consequently, against both the leaf miners and the other

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harmful enemies of pome trees, if chemical control is considered necessary, selective insecticides are used, to allow certain leaf miner parasitoids to survive. In certain cases, non-selective insecticides of short residual action, if used properly, may also have a selective effect. In general, organophosphorous compounds with short residual action, or those possessing an in-depth action (as e.g. dichlorvos), so that they kill the larvae inside the leaf. Also compounds inhibiting ecdysis, or others which prevent the normal hatching of the larva from the egg, such as buprofezin, diflubenzuron, fenoxycarb and triflumuron. In Switzerland, Charmillot et al. (1997a), against leaf miners of pome trees, recommend an intervention when 1-3 galleries per leaf are noticed (starting galleries).

Species of leaf miners infesting fruit trees belong to the genera *Gracillaria, Leucoptera, Lyonetia, Nepticula, Parectopa, Phyllocnistis, Phyllonorycter (Lithocolletis), Prays and Stigmella* (see below).

Phyllonorycter (Lithocolletis) blancardella **(F.)** (*Lithocolletis pomifoliella)* **(Lepidoptera, Gracillariidae)**

Adult. It has a length of 3.5 and a wing span of 8-9 mm. The basic color of the forewings is brownish with copper reflections. In addition, the forewings have two white stripes, a longitudinal and an oblique

Figs. 86-87. *Phyllonorycter blancardella.* 86.Adult. 87.Galleries in an apple leaf (photo S. Katerinis).

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one, as well as white spots with metallic reflections (Baggiolini 1960) (Fig. 86). The wings have long fringes. It resembles in shape, size and general coloration *P. corylifoliella***,** with which it often co-exists in orchards of pome trees.

Larva. The grown one is light yellow and approximately 5 mm long.

Host plants. Apple, pear, quince, *Mespilus germanica, Sorbus* sp., *Crataegus* sp., *Amelanchier* sp., *Rhamnus cathartica.* Kyparissoudas (1997) reports that in the area of Pella, northern Greece, this insect infested also the leaves of two cherry cultivars, and caused damage. In Italy, Hungary, and perhaps the Balcans, there is another related species, *P. cerasicolella,* which infests preferably the cherry and other stonefruit trees. Both adults and larvae of this species resemble very much those of *P. blancardella* (Zangheri et al. 1992) therefore, precise species identification is needed for leafminers infesting cherries and other stone fruits in Greece.

Life history and damage. In northern Greece, based on captures in pheromone traps, the male adult population had 4 peaks in Skydra and Rhahi Imathias, and 3 in Florina (Kyparissoudas 1988). From these data it is concluded that, most probably, the insect completes in those areas 4 and 3 generations per year respectively, as is generally the case in central Italy and southern Europe (Zangheri et al. 1992). It overwinters as pupa inside a cocoon in the larval gallery in the fallen dead leaves. The adults of the overwintered generation emerge in spring, mainly a little before or during the blooming of apple. The female oviposits on the underside of leaves. The neonate larva enters the leaf directly from the egg shell, and starts boring its gallery. At start the gallery is superficial, and later goes deeper and reaches the other (upper) leaf epidermis. The gallery is often oval, 12-15 x 6-7 mm and looks like a mosaic on the upper leaf surface, with whitish or light green specks against a green background (Fig. 87). The whitish specks are more dense in the perimetric zone of the gallery. On the undersurface of the leaf the larval gallery has a uniform color which ultimately becomes brownish. The front part of the pupa is outside the gallery (it protrudes from the leaf surface). The generations that follow develop overlapping one another in summer and autumn. In apple orchards of the Zagora area of eastern central Greece male adults were captured in pheromone traps from early May to late August in 1999. In 2000 the captures started in late April (Tsitsipis et al. 2007).

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Control. When absolutely necessary, it consists in spraying with a selective insecticide. Monitoring the adult population with pheromone traps, in combination with following up the hatching of young larvae, help in determining the proper time for spraying (Kyparissoudas 1988). In general, the control of this insect is the same as for most leaf miners of pome trees (see above, and Kyparissoudas 1997).

Phyllonorycter (Lithocolletis) corylifoliella **(Haw.)** (*Lithocolletis betulae*) **(Lepidoptera, Gracillariidae)**

Adult. It has a length of 4 mm and a wing span of 9-10 mm. The forewings have a general light red or light brown coloration (Zangheri et al. 1992). They also possess a longitudinal white line, a few oblique whitish stripes and a dark gamma-shaped stripe in the apical half of each forewing (Fig. 88). The hindwings are very narrow and darker in their basal part. Both the fore- and hindwings have long fringes.

Larva. It is 5-7 mm long and usually yellow green or yellow (Fig. 89).

Host plants. Of the cultivated trees it infests preferably the apple, pear and quince, and less so other Rosaceae such as *Mespilus, Crataegus, Cydonia, Prunus, Sorbus, Amelanchier, Cotoneaster* and *Chaenomeles.* It also infests the hazelnut and species of birch *(Betula).*

Life history and damage. According to Doxopoulos et al. (1963), at least 4 generations per year have been observed in the Naoussa area of central northern Greece. In Micra, near Thessaloniki, on pear, 3 generations were completed in 1975 and 1976, and 4 in 1977 (Savvopoulou-Soultani and Tzanakakis 1980). It overwinters as a grown larva in its gallery in leaves fallen to the ground. It pupates in spring and the adults appear in April, when the host trees have their first developed leaves. The females lay their eggs, one by one, on the upper leaf surface. The neonate larva enters the leaf directly from the egg, and at the beginning forms a superficial gallery, approximately circular or irregular, 1-2 mm long. This gallery of the young larva does not have a special color initially, but later becomes brown as it grows larger. As the larva grows its gallery expands and finally becomes spindle-shaped, oval, or often irregular and asymmetric (Fig. 90). The final length of the gallery is usually 10-15 mm, and not more than twice or thrice its width. The gallery is detectable only on the upper leaf surface, and often covers part of the mid-vein or a side-vein (for photo of the gallery see Zangheri et al. 1992). The larva feeds mainly

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Figs 88-91. *Phyllonorycter corylifoliella.* 88.Adult (Zangheri et al. 1992). 89.Larva in its gallery in the leaf. The leaf ephymenis has been removed to show the larva (photo N.T. Papadopoulos). 90.Larval gallery in a leaf (photo S. Katerinis). 91.Apple leaves heavily infested (photo B.I.K.).

on the palissade parenchyma below the leaf epidermis. The galleries of larvae of the last (autumn) generation which overwinters, differ in location and shape from those of spring and summer generations. The fully grown larva of the last generation spins a dense cocoon inside its gallery in the leaf. This dense weaving protects the larval gallery (Fig. 91) (Baggiolini 1960). Pupation will take place inside the cocoon in the leaf that ultimately falls. In central Europe this moth completes only 2 generations per year (Zangheri et al. 1992).

Control. In orchards where integrated control programs against pests of pome trees are applied, there is usually no need for special treatments against this leaf miner. The reason is that the surviving natural enemies of this miner, in conjunction with the measures against the other enemies of those trees keep the populations of *P.*

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corylifoliella to tolerable densities. In Greece, no economic injury population levels have been set for this insect, based on experimental data. Consequently we cannot decide whether insecticidal sprays against it, as applied in certain areas, are necessary. If necessary, the insecticides mentioned against other leaf miners will be used.

Leucoptera malifoliella **(O.G. Costa)** *(L. scitella, Cemiostoma scitella)* **(Lepidoptera, Lyonetiidae)**

Adult. It has a wing span of 6-8 mm and a light grey lead metallic color in the basal half of the forewings. The thorax, the abdomen and most of the forewings (except the apical one third) have also the above basic color. The forewings at the apical part of their front margin have white spots separated by ochroid stripes, and at their posterior margin, towards the apex, two dark spots often converging to form one dark oval spot (Fig. 92). The fringes of the outer margin of the forewings, as well of both margins of the hindwings, are long. The hindwings are very narrow, and of grey metallic color. The antennae are slender and long, with 32 articles (Zangheri et al. 1992).

Egg. It is brown, and when seen from above it is almost round, 0.3 mm in diameter, and slightly concave at the center.

Larva. The fully grown one is 4 mm long, and from light green-grey to brownish. The head and prothoracic shield are dark. The prothoracic shield is separated in two halves.The last 4 abdominal segments are narrower than the preceding ones, thus the larval body narrows towards the end. The abdominal prolegs (4 pairs) have each a full ring of 12-14 hooks (Real 1966).

Host trees. It is a polyphagous species, infesting various broad leaf, forest and fruit trees, such as pome and stonefruit trees. Apple and pear are considered hosts of preference. It occurs in all countries of central and southern Europe, in the Middle East and central Asia (Zangheri et al. 1992).

Life history and Damage. It completes 3 generations per year in northern and 4-5 in southern Italy (Zangheri et al. 1992). It overwinters as pupa in a whitish cocoon which somewhat resembles the letter H (Fig. 94). The cocoon is spun under dry bark or other refuges of the trunk and branches, and less often on dead leaves on the ground. The adults of the overwintering generation appear and oviposit in April

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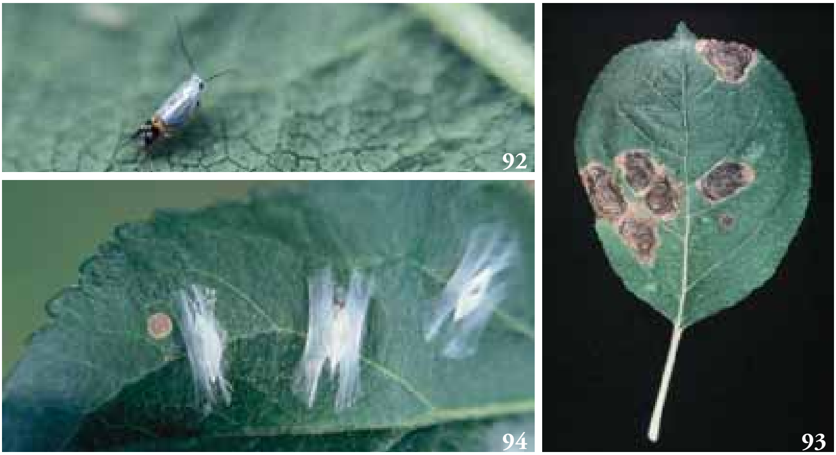

Figs. 92-94. *Leucoptera malifoliella.* 92.Adult (photo S. Katerinis). 93.Larval galleries in a leaf (photo R. Isler). 94.Pupation cocoons on a leaf (photo S. Katerinis).

(Zangheri et al. 1992). The female lays its approximately 50 eggs on the underside of leaves, between side veins. The neonate larva enters the leaf directly from the egg and, after passing through the spongy parenchyma, reaches the palissade one where it settles and feeds. It consumes the parenchyma moving at first spirally, creating a small, almost circular chamber. This gallery or chamber widens, and in the third larval stadium it is approximately 5 mm in diameter, while in the sixth (last) one up to 10-15 mm (Fig. 93). In Italy, the larval stage lasts 14-20 days in summer and more than a month in autumn. On apple the galleries are usually brown, lighter in the perimeter (see Zangheri et al. 1992). Having completed its growth, the larva usually hangs at the end of a thread it secretes and reaches a point of the bark or of a fruit, where it will select the site of pupation. Pupation at summer takes place also on leaves (Fig. 94). There is overlapping between generations after the first one. Over the gallery the upper leaf epidermis dries. The appearance of galleries and the degree of injury varies with the species of tree. The galleries weaken and kill the leaf partially or totally. When the galleries are many, 8-10 or more per leaf, and cover half or more of the leaf surface, leaf drop may occur, and under exceptional cases the whole year's foliage may be destroyed. However, damage from reduction of the active leaf surface is not serious. Foliage of the upper branches is usually infested more.

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Coccons of the summer generations located in the calyx or pedicel cavities may reduce the market value of apples (Zangheri et al. 1992). In the Naoussa area, the adults of the overwintered generation began appearing on the 20th April. Leaf infestation by larvae started in May and was maximal in July-August (Papoutsis 1957).

Control. Where integrated control of other insect and mite enemies of apple is applied, damage by this leaf miner is usually not serious and requires no separate control. If a serious infestation occurs, the control measures given against leaf miners of pome trees in general (see above) are recommended.

Lyonetia clerkella L. (Lepidoptera, Lyonetiidae)

Adult. It is a small moth, 2.5-3 mm long, with a wing span of 7-9 mm. The forewings are silvery in their basal two thirds, with a brownish apical third and an almost black spot at their apex, often with vertical stripes (Fig. 95). The hindwings are grey, very narrow, almost like needles, with dense fringes on their perimeter and especially long fringes along their posterior margin. The color of this insect may differ between races, but also between seasons within the year. The antennae are long, having two thirds the length of the forewings (Zangheri 1992).

Egg. Greenish, oval, approximately 0.5 mm long.

Larva. The young larva is greenish, almost transparent. Later it becomes green with a brown head, and a final length of 7-9 mm.

Pupa. Green, with the end of its abdomen bifurcate. It is within a long, loose cocoon, which the grown larva fastens with characteristic threads, forming an approximate X (Fig. 97) on the surface of a leaf of the host tree.

Host trees. Pome and stonefruit trees, mainly apple and cherry, but also broadleaf trees of other families.

Life history and damage. The number of generations per year varies with the region, and perhaps with the species of host tree. In Greece, according the Isaakides (1936a) it has 2 generations per year. Taking into consideration that in France and Germany 3 generations have been proven, the number of generations per year in certain areas of Greece, on certain species of trees, needs verification. It overwinters as adult in various sheltered sites. It becomes active in

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Figs. 95-97. *Lyonetia clerkella.* 95.Adult. 96.Larval gallery in an apple leaf. 97.Pupation cocoon on a leaf (photo H. Hoepli).

spring, when the first leaves of apple or cherry have developed. The female deposits each egg in a slit of the lower leaf surface which it makes with its extensible ovipositor. The neonate larva enters the leaf where it develops as a leafminer. Its gallery is sinuous and its width increases with larval age.The length of the gallery reaches 10-16 cm. (Fig. 96). The larva moves always forward and the last part of the gallery (near the larva) has no excreta. The gallery is at first yellow and later brown. Having completed its growth, the larva comes out of the leaf and spins the pupation cocoon on the underside of a leaf, usually other than the one it grew in (Fig. 97). The adults come out in 7-10 days and oviposit on leaves as described above. The populations of the generations after the first often overlap. The adults of the last autumn generation overwinter in protected sites in or near the orchard.

The larval galleries, especially when crossing one another and crossing the mid-vein or side veins, may prevent to a considerable degree the normal function of the leaf, thus causing nectotic spots, often large, or even causing leaf drop. Damage may be considerable only on young trees, where development may be delayed in years of heavy infestation. In such cases of heavy infestation, as many as 10 galleries per leaf were observed. In large, well maintained trees,

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damage has usually not been important in Greece. In countries of central Europe, *L. clerkella* is the most serious leafminer of pome trees.

Yponomeuta malinellus Zeller (Lepidoptera, Yponomeutidae)

Adult. It has a wing span of 16-20 mm, and a characteristic coloration. The head, thorax and forewings are white with widespread black dots (Fig. 98). The abdomen and the hindwings are grey. It much resembles *Yponomeuta padellus* which usually infests stonefruit trees.

Larva. It is light with a greenish dorsum and two brown hair-bearing tubercles in each body segment. Its final length is 18-25 mm. Both the larva and the adult look so much like those of some other species of the same genus, that one species may easily be taken for another.

Host trees. According to Martouret et al. (1966) it infests mainly apple.

Life history and damage. It has one generation per year. Many young larvae (first instar) overwinter in groups under the egg shells of the egg mass from where they have hatched (Fig. 99). They come out of that winter shelter in about mid-April, when the trees have their first tender leaves. They are gregarious, moving and living in a group. According to Martouret et al. (1966), they first bore a gallery in a leaf of which they consume the parenchyma, leaving the epidermises. Subsequently, when somewhat bigger, they unite with silk threads the apical leaves of a shoot, forming a loose nest, where they consume and destroy the leaves (Fig. 100). When their population is dense and they do not find enough leaves, they may eat the bark of tender shoots. After consuming the leaves of a shoot, they move to apical leaves of neighboring shoots, always making a group nest until they complete growth. In their last nest, in May-June, they spin their pupation cocoons, one near the other (Fig. 101). The adults appear in June-July and lay their eggs in groups (masses, plaques) of 25-70, preferably on the bark of two-year-old twigs, usually at the axils of buds or twigs. The larvae hatch in a few days and remain under the egg shells, weave a dense silk tissue and enter diapause. They become active in the following spring.

A parasitic hymenopteran, *Ageniaspis fuscicollis* (Dalm.), often limits considerably the population of this moth. However, there are

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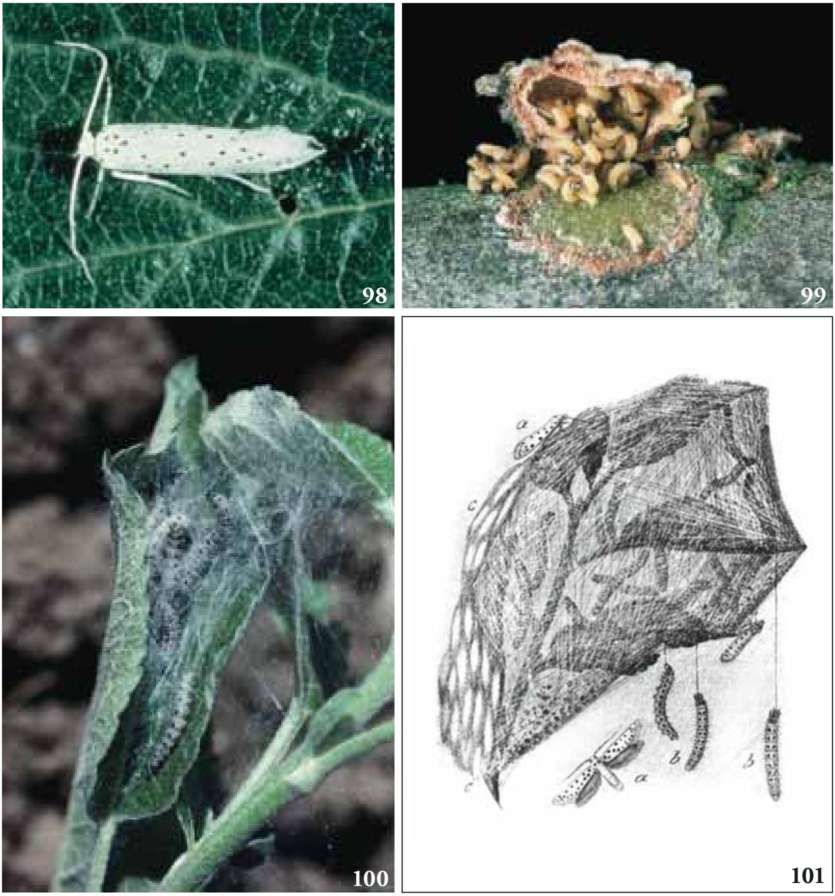

Figs. 98-101. *Yponomeuta malinellus.* 98.Adult. 99.Young larvae under their winter refuge, which has been lifted so they could be seen (photo H. Hoepli). 100.Nest with larvae near the tip of an apple shoot (photo B.I.K.). 101. Nest surrounding apical part of shoot and stages of the moth, in natural size. a adults, b grown larvae, c pupal cocoons (Sta. Firenze).

cases where the moth consumes almost all the leaves of an apple tree.

Control. Where the insect has done damage the previous year, a spray at the end of winter is recommended with a winter mineral oil, an organophosphorous insecticide, or a combination of the two. In early spring, as soon as larvae and erosions in a high percentage of leaves are seen, and before nests are formed, sprays with a suitable

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organic insecticide are carried out. When the larvae are in the second instar, satisfactory results are also obtained with formulations of *Bacillus thuringiensis.* When the nests are few, they are collected and destroyed mechanically or otherwise.

Wood- and bark-feeding insects

They are species whose larvae bore galleries in the wood and the bark of trees. Certain species are exclusively or mainly wood-eating (xylophagous). In those species the young larva enters from a suitable site of the bark, and bores a gallery in the bark to reach the wood, which is its main home and food. In certain other, mostly xypophagous species the larva during the first or also the second stadium bores its gallery in the bark, and later, during the following two or three stadia, proceeds to the wood. Other species are mainly bark feeders (phloeophagous). They bore their gallery in the bark, up to the cambium. Other species are both bark- and wood-feeders. In those species the gallery is approximately parallel to the surface of the branch and is in

Fig. 102. Group of galleries of a species of *Scolytus* on the inner side of the bark of the trunk of a fruit tree. From the vertical maternal gallery (on the left), start, at almost right angles to it, the filial (larval) galleries. At the end of each filial gallery (on the right) lies the fully grown larva in the pupation chamber (A.U.T).

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the inner layer of the bark, in the cambium, and in the outer layer of the sapwood, without going deeper. In species of this category, to which belong the bark beetles of the family Scolytidae (Ipidae), the adult female bores the “maternal gallery” along which it oviposits. The larval galleries start approximately perpendicularly to the maternal one, and subsequently follow a direction characteristic of the species of insect in a given species of tree (Fig. 102).

Most wood- and bark-feeding insects either preferably oviposit on, and therefore infest weakened or sick trees, or their larvae survive and develop better in such trees. Poor soil, lack of water, infection by fungi, by other plant pathogens, by other insects or mites, or even cracks of the bark because of sunburn or hail, favor the oviposition and the entrance of larvae, and increase the injury caused by those insects. To prevent or reduce injury, in most cases, measures are recommended that strengthen the host-tree and control the primary cause of weakening of the tree, e.g. fungal disease of the bark, of the vessels of the wood, or of the roots. Against those insects insecticides, cultural measures, mass trapping, mating disruption, or combinations of such measures are recommended, depending on each case. Certain species leave an opening of the gallery to the outside to empty their excrements. In this opening it is possible to introduce a suitable insecticide or, in some cases, a suspension of entomopathogenic nematodes that kill the larva.

Most species that injure fruit trees in Greece belong to the families Buprestidae, Bostrychidae, Cerambycidae, and Scolytidae (Ipidae) of the Coleoptera, and Sesiidae (Aegeriidae) and Cossidae of the Lepidoptera. For more information, in Greek, regarding these families, see Tzanakakis (1980).

Synanthedon myopiformis **Borkhausen** *(S. myopaeformis, Aegeria myopaeformis, Sesia myopiformis, Conopia myopiformis)* **(Lepidoptera, Sesiidae)**, comm. **apple clearwing moth, sesie du pomier**

Adult. It has a relatively slender body and a wing span of 17-25 or, according to some authors, 25-30 mm. Same as in all species of the same genus, the forewings are transparent in a large part, especially the basal part, and the hindwings almost wholly transparent. In other words, the wings have cells without scales. The parts of the forewings that bear scales and most of the body are blue-black with mild metallic

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reflections. In the female, the dorsum of the 4th abdominal segment (4th uromere) is orange red or bright red and the sides of the thorax orange (Fig. 103). In the male, the ventral surface of the tarsi and of the 4th, 5th and 6th abdominal segments is white. The abdomen has apically a tuft of relatively long hairs. According to Isaakides (1936a) in southeastern Europe there exists a variety *graeca* Stgr., in which the red abdominal zone extends to the 3rd and 2nd uromeres and the apical part of the forewings has dispersed yellow scales.

Egg. Whitish.

Larva. The fully grown one is 20-25 mm long and honey-yellow (according to other authors pale white) with a reddish line along the dorsum. The head and prothoracic shield are brown and the stigmata black (Fig. 104).

Pupa. Light brown.

Host trees. Mainly apple, pear and quince. However, it can also live in cherry, apricot, plum, *Sorbus* sp. and *Crataegus oxyacantha.*

Life history and damage. In northern Italy and central Europe in general, it is semivoltine, completing one generation every two years. In those regions it overwinters the first winter as a relatively young larva, and the second winter as a relatively grown one. In the Emilia-Romagna region of Italy it is considered univoltine, whereas in the Veneto semivoltine (Zangheri et al. 1992). In the Aghia Larissa area of central Greece, after three-year observations in apple trees, Sahinoglou et al. (1994-1998) conclude that the insect on apple in that area is most probably univoltine. It overwinters inside the larval gallery, in various larval instars, except the first. It pupates in a cocoon inside the bark, in a part of the gallery that the larva widens, after having made an exit hole to the outside for the adult to go through. Shortly before the adult emerges, the pupa crawls and reaches the exit hole. After the emergence of the adult, the anterior part of the puparium (pupal exoskeleton) protrudes from the bark surface, thus indicating the degree of infestation of each tree (Fig. 105). In the Aghia Larissa area, on apple, most pupae were recorded inside their larval gelleries from early April to late June, with a peak in late May to early June. In the same area, most adults emerged from mid-May to late June, peaking in June. Yet a smaller percentage of adults was trapped in pheromone traps later, until late September (Sahinoglou et al. 1994-1998). In the Zagora area of the same prefecture but at a higher elevation, the male moth captures in pheromone traps started

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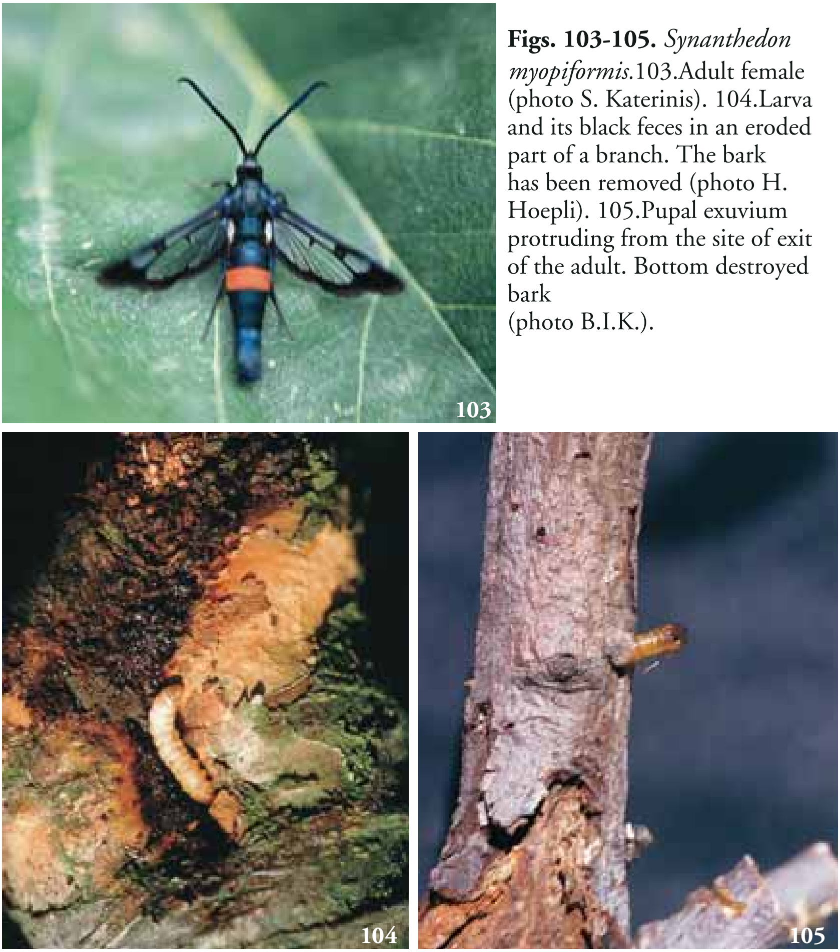

Figs. 103-105. *Synanthedon myopiformis*.103.Adult female (photo S. Katerinis). 104.Larva and its black feces in an eroded part of a branch. The bark has been removed (photo H. Hoepli). 105.Pupal exuvium protruding from the site of exit of the adult. Bottom destroyed bark (photo B.I.K.).

the second decade of May and continued until late August, peaking in early June, whereas in the year 2000 captures started approximately a week earlier, and continued until late July, peaking on the 22nd May (Tsitsipis et al. 2007). In Arnissa Pella of northern Greece, in a Starking Delicious apple orchard, the captures of adult males in pheromone traps began in mid-May and ended in late August, with the largest number of captures recorded from early June to late August, depending on the year (Kyparissoudas and Tsourgianni 1993). The adults to feed, visit flowers, especially of species of Umbelliferae. The rest of the time they remain on the trunk or protected in the foliage

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of host trees. They oviposit mainly in June-July. Oviposition after July is limited. The eggs are laid singly on the brim of wounds of branches that have thick bark, on lesions, pruning cuts, on generally sick or weakened parts of the tree, and even on hollow sites of healthy bark. The neonate larva enters the bark and bores a gallery in the bark and the cambium, without touching the wood according to some authors, or advancing to the sapwood according to others. The larval gallery is often winding and may even have branches. In the Aghia Larissa area most larval galleries were found near pruning cuts and at the graft site. This insect infests preferably old or weakened trees or parts of trees, or young trees at the site of union of the graft with the rootstock. The presence of more than one larva at the same site of a branch is frequent.

Injury by this moth, combined with injury caused by plant pathogenic microorganisms at the same sites of branches, results in weakening which may lead even to the death of branches or trees, especially when the galleries surround a branch. In cases of heavy infestation, more than 100 larvae of *S. myopiformis* have been recorded in certain trees. In certain European countries the damage to apple orchards in the last 30-35 years has increased. This is attributed to the spread of mechanical pruning, which causes more and larger wounds to the trees than hand pruning. In recent years, the importance of this insect as a pest of apple has increased also in eastern central and northern Greece (Sahinoglou et al.1994-1998 and references therein). In Switzerland, on pear trees, it has been verified that this insect is a secondary cause of injury to the trees. The primary cause are fungi of the genera *Leucostoma, Valsella* and *Valsa,* which become established in pruning cuts or other wounds and create lesions in the bark. Subsequently, the insect oviposits in the fissures of those lesions and the larval galleries favor the further spread of the lesions and the injury to the tree, which may result in the killing of branches (Baggiolini and Antonin 1976).

Control is difficult, because of the long period the adults are present in the orchard, resulting in a long period of egg laying and larval hatching. Therefore, more than one insecticidal sprays are required to kill the adults and the neonate larvae before they enter the bark. Sprays are carried out approximately every 3 weeks, with insecticides of long residual action, or of relatively short action but of medium volatility at high doses. The trunk and the limbs of the trees are checked from May on, to detect adult moth exits (puparia protruding

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from the bark), and sprayings begin as soon as an alarming number of puparia is recorded. Monitoring the adult population with pheromone traps is an easier but less accurate method, because those traps attract male moths also from neighboring orchards.

In certain countries where the insect is semivoltine, winter sprays have been recommended, using mixtures of parathion with mineral oil, or formulations such as oleoparathion. Such winter sprays are considered to kill the relatively young, first-year larvae overwintering in the bark, but not the grown second-year larvae. In the Aghia Larissa area, A.G. Koutroumpas et al. (unpuplished data) succeeded in killing most larvae, even of advanced age, with one spray of the trunk and limbs of apple trees up to a height of 1.5 meters, with a mixture of a summer oil and parathion, or by smearing with a brush a used lubricating oil from cars, the first half of November. Winter applications are aimed at reducing the injury to be caused the next year.

In Italy, two applications of a suspension containing the entomopathogenic nematode *Steinernema feltiae* gave satisfactory results (for details see Deseö et al. 1986). On pear in Switzerland, indirect measures are also recommended, that is to control the fungi and other plant pathogenic microorganisms which cause necroses, fissures, or lesions in the tree bark. The female moth is thus less prone to oviposit on healthy bark, and the entrance and settling of neonate larvae less easy. In this respect it is recommended to prune carefully to the very base of the removed branch or twig, and to disinfect the pruning cuts with a fungicidal ointment. Also, to prune late (shortly before bud development) so as to reduce the probability of infection of the wounds by *Leucostoma* and *Valsella* fungi. Where there are lesions, removing the dead or sick bark and disinfection with a fungicidal ointment (paste) is recommended by Baggiolini and Antonin (1976).

The mating disruption method, by placing sex pheromone evaporators in the trees, was tested in two neighboring Starking Delicious apple orchards in Arnissa Pella, northern Greece (Kyparissoudas and Tsourgianni 1993). In the third consecutive year of applying this method, the reduction of the number of adults emerging from the galleries was 88.6% in the one and 94.4% in the other orchard. This encourages the further testing of this method in the same area, as well as elsewhere.

Another species of the same family, *Conopia typhiaeformis*

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Borkhausen, infests in a similar way mainly apple and less often quince and pear trees. The adult male is uniformly dark green, while the female has two red transverse stripes in the abdomen, the posterior one being wider (Silvestri 1943).

Cossus cossus L. (Lepidoptera, Cossidae)

Adult. It is among the largest insects that infest trees in Greece. The female has a wing span of 70-100 mm. The male is smaller. The body is bulky, felty, hazelnut-grey, lighter in the posterior part of the pronotum. The general coloration of the wings is also grey and resembles that of the bark of certain trees. The forewings have many small wavy transverse dark lines. The hindwings have approximately the same general coloration as the forewings, but more uniform and have their basic part fuzzy (Fig. 106). When at rest, the adult keeps its wings closed, parallel to the body and at an angle like a roof.

Egg. Elliptical, 1.7 x 1.2 mm, brownish with black lines and longitudinal grooves. Eggs are often in groups of 15-50.

Larva. The young larva is pink or meat-colored on the dorsum, and yellowish on the pleurae and the venter. The grown larva is darker on the dorsum, usually dark red or redbrown, and whitish or yellowish on the venter. Fully grown it is 80-100 mm long and up to 15 mm wide (Fig. 107). The head is black, of a final width of 7 mm. The prothoracic shield is also black and separated in two parts. With its mandibles and maxillae the larva can give a painful bite to the person that tries to hold it. It has a strong characteristic odor, like that of old moldy leather.

Pupa. It is rust-brown, and the female dimensions are 50-60 x 16 mm. It has two transverse rows of spines on each of the second to seventh abdominal segments. These spines help the pupa push its body to the exit hole before the adult emerges.

Host trees. The larva is a polyphagous wood eater. This species infests many and various broad-leaved fruit and forest trees, but especially weak ones, recently cut, or dead. In Greece it frequently infests olive, apple, cherry, pear, plum, quince, peach, apricot, chestnut, mulberry, walnut, oak, elm, willow, plane, ash and poplar. It is widely distributed in the palaearctic region.

Life history and damage. The life cycle is completed in 2 or 3

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years in Mediterranean countries. It passes the last winter as a fully grown larva and pupates in spring, in a pupation chamber which it forms by widening its gallery near the surface of the bark. The adults appear in May, June and July and oviposit in fissures of the tree bark, usually at a height of 1.5-2 m. In the Yannitsa Pella area of northern Greece, in apple and pear orchards, the captures of adult male moths in pheromone traps began in late May to early June, and ended in late August (Kyparissoudas et al. 1997). The neonate larvae enter the bark, and in the first year do not surpass the cambium. In winter they remain inactive. They become active in spring and continue boring their gallery deaper, in the wood. Those that complete growth in autumn, will overwinter as larvae in diapause and in spring they will make their pupation chamber near the tree surface and pupate. Those that will not complete growth in the autumn of the second year, will continue their growth until the autumn of the third year and overwinter likewise as fully grown larvae. The larval gallery in the wood is as a rule ascending and elliptical in cross section. The

Figs. 106-107. *Cossus cossus.* 106.Adult with open wings left, and closed wings right (photo B.I.K. and R. Angelini from Zangheri et al. 1992, respectively). 107.Larva outside its gallery (photo H. Hoepli).

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presence of the larva in the tree becomes knowm by its reddish excrements which accumulate like a dust at the base of the trunk under the larval gallery.

Cossus cossus is one of the most common xylophagous Lepidoptera in Greece, and contributes to the further weakening or the death of weak trees. However, in the warmer areas of Greece, considerable injury is observed also on trees that are not weak. On the islands of the eastern Aegean, including the Dodecanese, *C. cossus,* together with another wood borer, *Zeuzera pyrina* (below), cause serious injury to olive trees, whereas in continental Greece they injure mainly fruit trees of the Rosaceae.

Control. Effective control measures have not been suggested, except the mechanical or chemical killing of the larva in its gallery. It is believed that in cases of serious infestation of healthy trees, measures similar to those recommended against *Zeuzera pyrina* (see below) will be effective. The use of pheromone traps helps in timing the insecticidal applications against the adults and hatching larvae.

***Zeuzera pyrina* L. (Lepidoptera, Cossidae)**, comm. **leopard moth**

Adult. It is a relatively large moth, 25-30 mm long, with a wing span of 55-70 mm in the female and 35-40 in the male. The hindwings are considerably smaller and shorter than the forewings. It has a characteristic coloration. The thorax and wings are white, with many small, circular or oval blue-black spots. The abdomen is grey-black (Fig. 108).

Egg. Oval, somewhat long, yellow-red to brown-red, approximately 1 mm long.

Larva. Whitish or yellow, with characteristic black setiferous tubercles on the dorsum, and dark brown head, prothoracic shield and anal shield (Fig. 109). When fully grown it is 50-55 mm long and 8 mm wide.

Host plants. It is a polyphagous wood borer. It can complete its life cycle on approximately 150 species of perennial plants. It infests mainly pear, apple and olive, and less so quince, plum, walnut, and other fruit, forest and ornamental trees and shrubs. While in continental Greece it infests and injures mainly pome trees, on the islands of the eastern Aegean and the Dodecanese it causes serious damage mainly

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Figs.108-110. *Zeuzera pyrina.* 108.Adult (photo B.I.K.). 109.Larva in a shoot of the season (photo S. Katerinis). 110.Pupal exuvium at the site of exit of an adult (photo B.I.K.).

to olive, as happens also in warm regions of southern Italy, Turkey, Syria, Israel and Jordan. It is not known why this insect infests and injures mainly olive in certain warm regions and mainly pome trees in most other regions. The possibility of a genetically different strain adapted to olive is worth investigating. For details regarding its life history on olive see chapter on insects of olive.

Life history and damage. Usually it completes one generation every 2 years. It overwinters as larva inside the tree trunk. It pupates in spring of the second year inside the larval gallery near the surface of the bark. The adults appear in June, July or later, in August, and lay their 100-300 eggs singly or in groups in fissures of the trunk or the branches. In the Yannitsa Pella area of northern Greece, in apple and pear orchards, the captures of male adult moths in pheromone traps began in mid-June and ended the second decade of August (Kyparissoudas et al. 1997). According to most researchers, the larva enters the trunk or branch and bores a gallery in the wood, progressing up to the pith. The gallery has a length of 25 cm or more (according to Féron and Audemard (1962), up to 40 cm). The shape and location of the gallery varies with the species and the size of the

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tree or the branch (Fig. 109). Every larva lives alone in its gallery. It usually keeps an open hole in the bark, from where it pushes out wood dust and its granular excrements, which are orange-colored. The presence of an orange-colored dust on the tree trunk, or on the soil below, indicates the presence of a larva in the tree. The larva completes growth usually in the autumn of the second year. Then it returns to the part of the gallery near the hole to the outside, widens that part to a pupation chamber and pupates there in the following spring. During the exit of the adult, the puparium protrudes from the surface of the bark, thus showing that an adult has emerged there (Fig. 110).

In northern Italy, the life cycle of the insect on apple is completed in one or two years, depending on when are deposited the eggs from which a given life cycle begins. Larvae hatching from eggs laid early, complete the larval stage in the same year, and overwinter only once as fully grown. Therefore, the cycle in those larvae is annual, the insect thus being univoltine. Larvae hatching from eggs laid later, at the end of summer or in autumn, pass the first winter as relatively young larvae, continue growth in the warm season of the next year, and overwinter as fully grown that year. In those larvae the life cycle is biannual, the insect being, therefore, semivoltine (Deseö and Kovács 1977, Zangheri et al. 1992). In northern Italy, according to Deseö and Kovács (1977), the eggs are deposited not only on the trunk and limbs, but also on twigs. The neonate larvae search for a suitable site to enter the tree. During that search on the tree surface they may move for a meter or more. At first they enter buds, midveins of leaves and pedicels. Subsequently they extend their gallery to slender shoots and twigs and further to branches of larger diameter. Later, in most cases, they proceed to the surface layers of the trunk and ultimately to the inner layers. The behavior of the young larva seems to be similar in southeastern France (Féron and Audemard 1966). There, the eggs are laid also on twigs and the young larva first infests young shoots, entering from a leaf stalk, a midvein of a leaf, an axillary bud, or other site. For a week or two it bores its gallery in a young shoot of the season, or in a twig, and subsequently abandons it to go to a lower (more basal) part of the tree and enter a limb or the trunk. This larval activity on the outer parts of the canopy exposes the larva to the insecticides which are sprayed against the codling moth and some other enemies of pome trees.

The leopard moth is a serious enemy of pome trees and, on certain

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Greek islands, of olive trees. A single larva may kill a young, 1-3-year-old tree, or cause its breakage by strong wind. On trees of medium and older age whole limbs or lower branches are killed and break under strong wind. The degree of damage varies with the species and cultivar of the tree, as well as with the orchard conditions.

Information that concerns *Z. pyrina* as a pest of olive trees is given in the chapter on insects of that tree.

Control is difficult, because of the long period adults are present and oviposit (from early summer to early autumn), and also because the larvae during most of their life are protected inside the tree. A preventive measure are sprays of the trunk and branches in summer, to kill the neonate larvae before they enter the tree. Good results have been obtained with certain organophosphorous insecticides sprayed every 15 days from early June to mid-August (Anonymous 1973). With the use of pheromone traps, the period of the presence of adult moths is determined more acurately in each area, so as to protect the trees with as few sprays as possible. To this end, certain insecticide sprays against the codling moth may also kill leopard moths if properly applied. As a preventive measure the whitewashing of trunk and limbs is suggested, which is believed by some people to discourage oviposition, or the entrance of the young larvae in the tree. Against larger larvae in their galleries the use of antilarval matches releasing phosphine or other fumigant is recommended. These matches are introduced through the hole of the larval gallery to the outside. Also recommended are injections of phosphamidon, gasoline, diesel oil, carbon bisulphide, or other suitable insecticide, and plugging the hole with mud or other material. Pushing a wire into the larval gallery to kill the larva, as many fruit growers have done for years, is another measure to consider.

In Italy, on apple and pear trees, the leopard moth was also controlled by introducing in each larval gallery cotton wicks impregnated with a water suspension containing the entomopathogenic nematode *Sreinernema carpocapsae* Weiser (Deseö 1982). In northern Italy, where one generation is completed in 2 years, Deseö and Kovács (1977) found effective the spraying of apple trees in March or also in April, at the points excrements come out of the bark, with high concentrations of the organophosphorous insecticides chlorpyrifos (8%) and monocrotophos (3%). Later the same researchers recommended, as less dangerous to the spray applicator, a mixture of 750 ml water, 250 ml emulsifiable polybutane and 1 g chlorpyrifos (Deseö and

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Kovács 1978). The exit of a brown liquid from the holes 2 weeks later indicates that the larva was killed. Also they recommend the timely removal and destruction of the shoots and twigs having galleries. In tree nurseries an autumn spray is recommended in mid-October with 0.3% chlorpyrifos. In Italy, on nursery trees, good results were obtained with sprays with teflubenzuron and triflumuron every 20 days, starting 3-4 weeks after the beginning of captures of male moths in pheromone traps (Pasqualini et al. 1996). In Italy, mass trapping of male moths on sticky traps with pheromone was also tested (Vettori and Pasqualini 1997). Some fruit growers prefer to kill the larvae mechanically, with a wire they introduce in the larval gallery.

Leaf rollers

They are Lepidoptera of medium size, belonging to the family Tortricidae. The adults have wings generally broad, with fringes shorter than the width of the wings. When keeping the wings folded, many species on dorsal view look bell-shaped. The adult moths are active mainly at dusk. The eggs are laid on leaves, buds, or on the bark of shoots and branches. The larvae connect with threads neighboring leaves, or even roll or fold them to create a sort of nest where they live protected. They are mainly leaf-eaters, but can injure also buds, tender shoots, flowers and the surface of fruits (Figs. 111-113, 126). They are lively, and move quickly forward or backward when disturbed. They pupate usually on the plant, unless they do not find there a suitable shelter to spin the pupation cocoon. There are univoltine and multivoltine species. Among the enemies of fruit trees and grapevine are species of the genera *Adoxophyes, Archips,*

Fig. 111. Tender apricot leaves infested by larvae of a leaf-roller (photo B.I.K.).

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Figs. 112-113. Injury by larvae of leaf-rollers. 112.To young peach (photo B.I.K.). 113.To pears infested when young (A.U.T.).

Argyrotaenia, Cacoecimorpha, Choristoneura, Hedya, Pandemis and *Sparganothis.*

Adoxophyes orana **Fischer von Roesslerstamm**
(A. reticulana, A. fasciata, A. tripsiana, Capua reticulana)
(Lepidoptera, Tortricidae), comm. **summerfruit tortrix, capua**

Adult. The wing span is 15-10 mm in the male and 19-22 in the female. In the male the forewings are ochre yellow to reddish and have distinct rust-red markings (for details see Bovey 1966). The female forewings are usually darker than the male, often dark brown, and have darker and less distinct stripes and other markings (Fig. 114).

Egg. In groups, usually on the upper leaf surface of apple, and the lower leaf surface of pear, peach, and plum (Zangheri et al. 1992) (Figs. 115, 116). In Switzerland and nothern Greece, many more than 16 eggs per mass have been observed in certain cases (Figs. 115, 116).

Larva. The fully grown one is 18-20 mm long, green, and has a light green head (Fig. 117).

Host plants. It is a polyphagous species. It develops in plants of more than 30 genera, among which fruit trees of the Rosaceae, grapevine, ornamental Oleaceae, oaks, poplars, and willows. It has a wide geographical distribution, covering most of central and northern Europe and Asia (Savopoulou-Soultani et al. 1985, Charmillot and

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Brunner 1989, and references therein). It is a pest of fruit trees also in northern Greece.

Life history and damage. In Switzerland *A. orana* completes 2 generations per year on apple (Charmillot and Brunner 1989). In northern Greece it completes 3 to 4, depending on the locality and species and condition of the host tree (Kyparissoudas 1988, Savopoulou-Soultani and Hatzivassiliadis 1991, Milonas and Savopoulou-Soultani 2006, Damos and Savopoulou-Soultani 2010a). It overwinters as third-instar larva in a silk nest which it weaves in a fissure of the bark, under dry bark, or at another protected site, usually on the tree (Fig. 118). The larva comes out of its winter shelter in spring, to feed on tender new tree growth (developing buds, flowers, tender leaves, tender shoots) (Figs. 119, 120). Pupation takes place between infested plant organs. The young larvae of the first generation feed on tender leaves on the tips of young shoots. When they become third instar they begin to roll and unite with silk threads neighboring leaves. Infestation at that stage is not detected easily. Larvae of the last (5th) instar attack also fruits, especially if one touches another fruit or a leaf and larval population density is high (Fig. 121). The larvae of the other summer and autumn generations behave in a similar manner.

In the Naoussa area, on apple and pear, the larvae that overwintered become active in late March to early April. The adults of this (3rd) generation appear mainly in May, with most of the population in mid- to late May. Most adults of the next (first) generation are observed from early to late July, and those of the second generation from mid- to late September (Savopoulou-Soultani and Hatzivassiliadis 1991). The larvae of the first generation span the period from late May to late July, those of the second generation from mid-July to late September, and those of the third one from mid-September to early or mid-May (Savopoulou-Soultani and Hatzivassiliadis, unpublished data). According to Kyparissoudas (1991), in the low-elevation zone of central northern Greece the insect completes 4 generations per year. The larvae of the first generation span the period from mid-May to 10 June, those of the second generation from early July to early August, of the third one from approximately 10 August to 10 September, and those of the fourth generation from mid-September to approximately 20 April. On peach, in the same general area where only 3 generations have been recorded per year by Milonas and Savopoulou-Soultani (2006), the first moths were captured in early May. A second flight period occurred in July and a third one in late

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August to mid-September.

In northern Greece this insect, in addition to apple, pear and cherry (Savopoulou-Soultani et al. 1985), has become a major pest of peach. In that region, its population dynamics on peach have been studied using pheromone traps and weekly examination of foliage infested by the larvae. Three generations per year have been confirmed on peach, as shown by 3 periods of adult flight and also 3 periods of larval activity during the season (Milonas and Savopoulou-Soultani 2006 and references therein, Damos and Savopoulou-Soultani (2010a). One of the reasons that 4 generations have been completed on apple may be that larval growth on apple foliage is faster than on peach foliage (Skoulakis 1997, as cited by Milonas and Savopoulou-Soultani 2006).

Prolonged tender growth favors the feeding of larvae and creates dense populations of this species, with resulting considerable damage. In Switzerland, the population density of this insect is always lower in orchards which have limited yearly growth (Charmillot and Brunner 1989).

Control. Charmillot and Brunner (1989) summarize the life history of this insect in Switzerland on apple trees, compare them with earlier life history data from northern Greece, and discuss techniques to monitor and manage it. Their first target is the reduction of the population of the generation that has overwintered, so that the population remains in tolerable densities also during the following generation which there attacks fruit. This is achieved by spraying a juvenile hormone mimic, such as fenoxycarb, a few days after full bloom of the Golden Delicious cultivar. This application prevents pupation, and should be effected on the generation that precedes that which injures the fruit. The second target is the young larvae of the generations that injure fruit. This is achieved by spraying a synthetic insecticide, mainly organophosphorous, during the hatching of larvae. Based on the same principles, Kyparissoudas (1991) recommends a spray against larvae in mid-April with fenoxycarb, or earlier, in late March, with another insecticide, e.g. an organophosphorous one. On the European market one can find a formulation of a virus (GV) pathogenic to this insect, under the commercial name Capex. This formulation is effective against young larvae. Strains of another virus (IPV) proved even more effective (Deseö-Kovács and Rovesti 1992).

Mating disruption by spreading a sex pheromone in the orchard gave in other countries, as a rule, satisfactory results when the insect population density was low, but not when it was high (Charmillot

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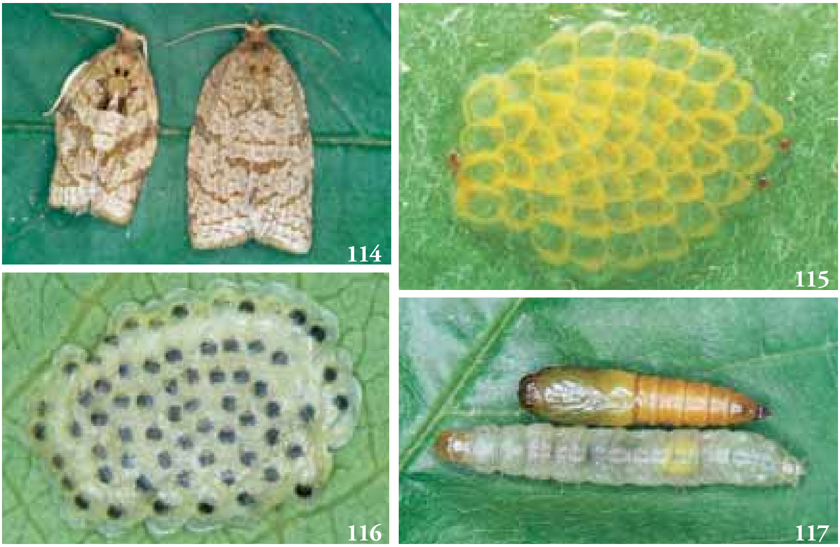

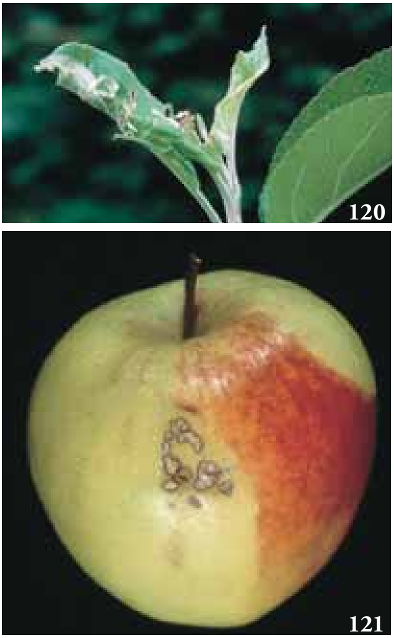

Figs. 114-121. *Adoxophyes orana.* 114.Left adult male, right adult female (photo N.T. Papadopoulos). 115.Recent egg mass (photo A. Staub). 116.Egg mass with developed embryons (photo N.T. Papadopoulos). 117.Fully grown larva and pupa (photo N.T. Papadopoulos). 118.Overwintering cocoons (white) in fissures of the bark (photo B.I.K.). 119-120. Infestation of tender growth (photo A. Staub and S. Katerinis respectively). 121. Healed erosions of a fruit (photo H. Hoepli).

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and Brunner 1989). The first year an insecticidal spray is applied in spring to reduce the insect's population, and subsequently pheromone evaporators are placed on the trees to keep the population at an acceptable level. In Switzerland the pheromone evaporators contain also the codling moth sex pheromone, so as to achieve a simultaneous control of both species of moth (Charmillot et al. 1997a).

As pointed out by Damos and Savopoulou-Soultani (2010a), detailed information on the adult moth flight patterns of this and the other two major lepidopterous pest species of peach are key factors in constructing effective forecasting and managing programs. Those planning to engage in integrated control of Lepidoptera infesting stone and pome fruit trees in northern Greece, are advised to consult their paper.

During their three-year study, Milonas and Savopoulou-Soultani (2006), found *Colpoclypeus florus* Walker (Eulophidae) to be the most frequent of three species of parasitoid wasps parasitizing larvae of the moth. Yet, total parasitism of larvae of *A. orana* remained low.

Archips rosanus **L.** *(A. laevigana, Cacoecia rosana)* **(Lepidoptera, Tortricidae)**, comm. **apple leaf roller**

Adult. It has a wing span of 18-22 mm. The basic coloration varies. Also the sexes differ in the coloration of the forewings. In the male the forewings are from light brown-yellow to grey-brown, and usually have a rust to grey-brown macula at the base and two bands from the middle backwards (Fig. 122). In the female the macula and bands are less clear than in the male (Fig. 123). The hindwings are in both sexes grey-brown and towards the apex yellowish.

Egg. On dorsal view it is oval, green, 0.5 x 0.3 mm. The eggs are laid in groups of a few to several dozen, and on the average 40-50 eggs per group (egg mass) (Fig. 124). In every group each egg partly covers the neighboring ones, and all are covered with a transparent substance which makes them tolerant to most insecticides that the grower uses in winter.

Larva. Fully grown it is 10-22 mm long. The color changes with the instar. In the first instar it is yellowish, in the second one yellow-green, and in the following instars green, often oily. In the last (5th) instar the body color can be green-grey, purple, or reddish. The head is dark brown, the prothoracic shield and the thorasic legs brown, and

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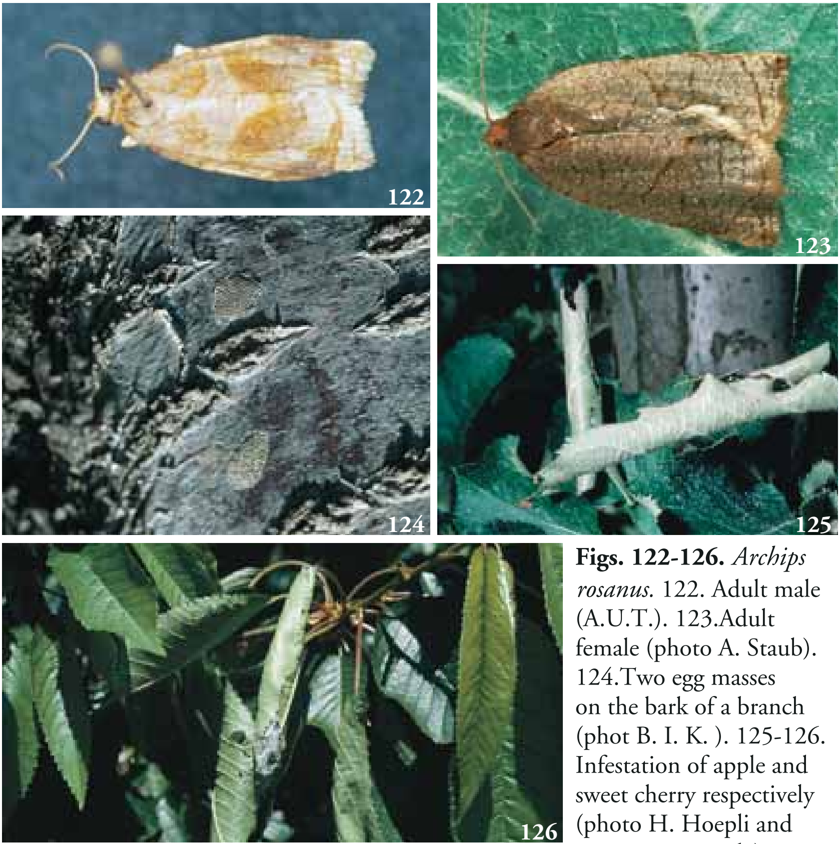

Figs. 122-126. *Archips rosanus.* 122. Adult male (A.U.T.). 123.Adult female (photo A. Staub). 124.Two egg masses on the bark of a branch (phot B. I. K.). 125-126. Infestation of apple and sweet cherry respectively (photo H. Hoepli and B.I.K. respectively).

the anal shield usually white yellow.

Pupa. Yellow-brown, 7-10 mm long, in a cocoon, between rolled leaves.

Host trees. It is polyphagous, perhaps the most polyphagous leaf roller of fruit trees in Greece. In central Europe it infests mainly apple and pear, and is known as the apple leaf roller (Bovey 1966). In Greece it frequently infests stone fruit trees and pistachio, but a heavy infestation of foliage of orange was also observed in Argolis of central Greece (Mourikis and Vassilaina-Alexopoulou 1974). In other countries it is a serious pest also of hazelnut.

Life history and damage. It has one generation per year. It overwinters in the egg stage on the bark of host trees. Hatching of

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larvae takes place in March-April and the larvae grow and develop mainly in April and May. The young larvae settle on apical developing buds. Later they are found mainly on leaves, although they also infest shoot tips, flowers and young fruits. The larva connects with silk threads the plant parts it settles at, thus forming a shelter (nest) in which it lives and develops, consuming the plant tissues in and around it. Its shelter may consist even of a single leaf which it rolls to form its refuge. If the old refuge becomes unsuitable, the larva forms a new one. Therefore the larva of *A. rosanus* has the typical behavior of a leaf-roller. It pupates in the foliage, inside its refuge, usually in May. Infested sites of shoots are usually evident, because of their rolled or united leaves (Figs. 125, 126). The adults come out of the puparia in May and June. After a few days they oviposit, and the eggs remain in diapause from June-July through most of the following winter. Every female lays up to 300 or even more eggs. On orange trees in Argolis, hatching started in late February to mid-March and the larvae were fully grown from late April to late May. The adults span the period from mid-May to mid-June (Mourikis and Vassilaina-Alexopoulou 1974).

Damage to foliage, flowers and fruit depends on the population density of the insect. When fruits are very small, they are destroyed. Later, fruits are eroded superficially and as they grow become distorted, or have scars which lower their commercial value (Fig. 113). Similar injury to fruit trees is caused also by other species of leaf-eating Lepidoptera.

Among its many natural enemies are birds, which eat all stages of this insect, an oophagous mite, and many parasitic Hymenoptera. Among the latter, the oophagous *Trichogramma embryophagum cacoeciae* Marshal, is considered an effective natural enemy of *A. rosanus.*

Control. A spray with an organophosphorous contact insecticide is recommended only if considerable damage by this insect occurred in a given orchard the previous year, and a large number of egg masses is observed in winter. The spray should be applied during the period of hatching of most larvae. This usually occurs on pome trees shortly before bloom, on stonefruit trees in mid-March to early April, and on citrus in Mid-March. To protect oophagous parasites, it is recommended to avoid insecticide applications during the egg stage. An additional reason is that the eggs are resistant because of the protective substance that covers them.

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Cydia pomonella **(L.)** *(Carpocapsa pomonella, Laspeyresia pomonella)* **(Lepidoptera, Tortricidae)**, comm. **codling moth, apple worm**

Adult. Body length 7-10 and wing span 14-24 mm. The coloration is characteristic and not confusable with those of other species of moth than infest pome trees, except that of one closely related species of the same family, *Laspeyresia pyrivora,* which infests only cultivated and wild pears. The forewings have a grey or grey-brown coloration with fine brown or brown-black cross lines. In many individuals, the basic third of the forewings is distinctly darker than the middle third. Near the apex, towards the anal angle, the forewings have a relatively large dark spot, the speculum. This characteristic spot has a basic brown color, and is framed by two bronze-colored shiny lines in a shape of parentheses. The inner line (towards the wing center) has near and alongside it a narrow black stripe. Along the foremargin (costa) of the forewings there are small dark curved lines, which become more accented in the apical half of the wings. The fringes are golden (Fig. 127). The hindwings are brown towards copper, with golden reflections. They are darker towards the perimeter, and have at the base of the cubitus a group of long dark hairs shaped like forceps. In the female, on their under surface, both pairs of wings have the same coloration, grey-brown with copper reflections, whereas in the male the forewings have a little before their middle a dark, almost rectangular spot.

Egg. According to Zangheri et al. (1992), on dorsal view it is approximately circular. The color varies from grey-yellow or whitish opalescent soon after deposition, to orange, with an incomplete carmin red ring in the periphery. Eggs are laid singly, and rarely in groups of 2 or 3. Those of the first generation are laid almost exclusively on leaves close to fruiting organs, and those of following generation(s) mostly on fruits and especially on the parts more exposed to the sun.

Larva. The newly hatched larva is whitish, with blackish head and prothoracic shield. As it grows and changes instars it becomes pale yellow and pink on the dorsum. The body has numerous small setiferous tubercles. Final length 18-20 mm. The overwintering fully-grown larva has a white body, with the head, prothoracic shield and anal shield dark brown. It does not have an anal pecten, in contrast to the larva of *Laspeyresia molesta* (Della Beffa 1961, Zangheri et al. 1992).

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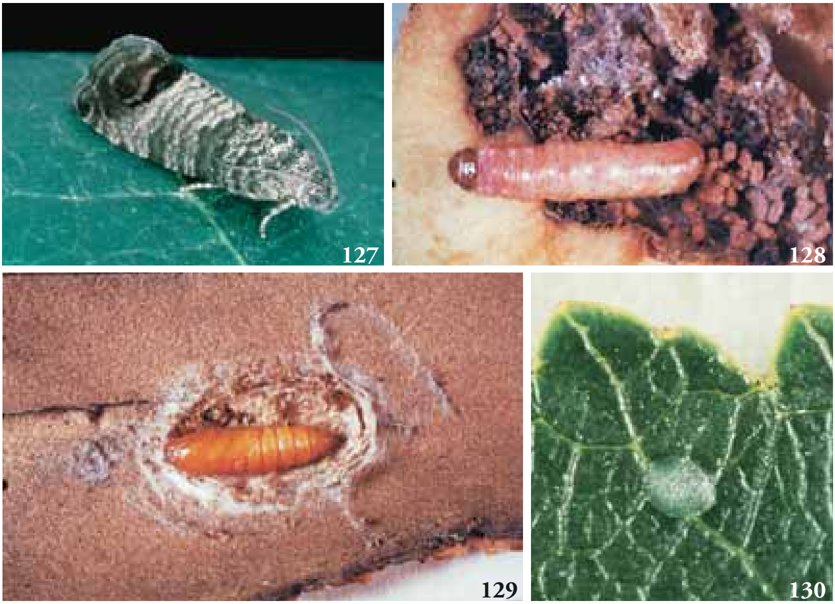
Pupa. Light brown.

Host trees. Apple, pear, walnut, quince, apricot, peach, almond, plum. Usually it infests fruits of the first four species. Infestations of the rest are limited, and depend on the region, and moth populations



Figs. 127-130. *Cydia pomonella.* 127.Adult at rest (photo H. Hoepli). 128.Last-instar larva. 129.Pupa (A.U.T.). 130.Egg on a leaf (photo A. Staub).

adapted to certain cultivars of these stonefruit trees (see Barnes 1991). Exceptionally, the larva can develop in fruits of persimmon, *Sorbus*, chestnut, *Eriobotrya japonica*, pomegranate, and orange (Bovey 1966).

Life history and damage. The number of generations per year varies, mainly with the climate of the region. In Greece it completes usually 2-3 generations, while in cold climates only one. Yet, there are cases of bivoltine and univoltine populations within the same general climate area, on different species or cultivars of the host tree (Barnes, 1991). It overwinters as a fully grown larva (Fig. 128) in a cocoon under dry bark, fissures of trunk and branches, or in various other refuges and the soil near the tree where it grew. On trees with smooth

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bark, where the number of refuges is limited, the percentage of the larval population overwintering in the soil is higher. Pupation (Fig. 129) occurs in spring, and the adults appear in April-May. In northern Greece they appear mainly in May, and their population maximum is observed 1-2 weeks after petal fall of the Red Delicious apple cultivar. The female lays its eggs singly on leaves, small shoots, or small fruits (Fig. 130). The young larva, after walking to reach a young fruit, enters it usually at the calyx cavity. However, it can enter a fruit also at other points, especially where a fruit touches a neighboring fruit, a leaf, or a twig. The larva, being a fruit borer, directs its gallery to the fruit center where the seeds are, and eats the tender seeds and the fruit flesh. It discharges its granular feces from the gallery through a hole it keeps open, usually on the side of the fruit (Figs. 131, 132). This hole, with the dark larval feces often retained around it, is quite evident and shows the presence of a larva in the fruit. A small young fruit often does not provide sufficient food for a larva to complete its growth, and it is reported that the first-generation larva infests a second fruit to complete its growth (Avidov and Harpaz 1969). The fully grown larva abandons the fruit and pupates, always in a white cocoon, under dry bark, fissures of the bark, and if need be in the soil. The adults of this (first) generation appear usually in July, and the females oviposit maily on fruits and, according to certain authors, also on shoots and leaves. Barnes (1991) reviewed lucidly the literature on the occurrence and host race formation in the codling moth, as well as the damage caused to various host fruits. He cites sources from Canada, where most eggs were laid on the smooth upper surface of apple leaves close to fruits, and considerably fewer eggs on fruits themselves. On pear, the favorite sites for oviposition were the lower surfaces of fruit cluster leaves. On quince the upper leaf surface was preferred for oviposition, the pubescence of the lower surface being a deterrent (Bovey 1966). In California on walnut in spring, oviposition was entirely on leaves and green twigs, as the nutlets were densely pubescent (Olson 1977, from Barnes 1991).

The young larva of the second generation enters the fruit usually at the point of contact with another fruit, shoot or leaf. It completes its growth in that fruit, and weaves its overwintering cocoon in a protected site on the tree or even in the soil. In relatively warm areas and where fruits are still found on the trees, it is thought that a third generation develops. On walnut, the first-generation larva develops in the mesocarp and endocarp, whereas the second-generation one in

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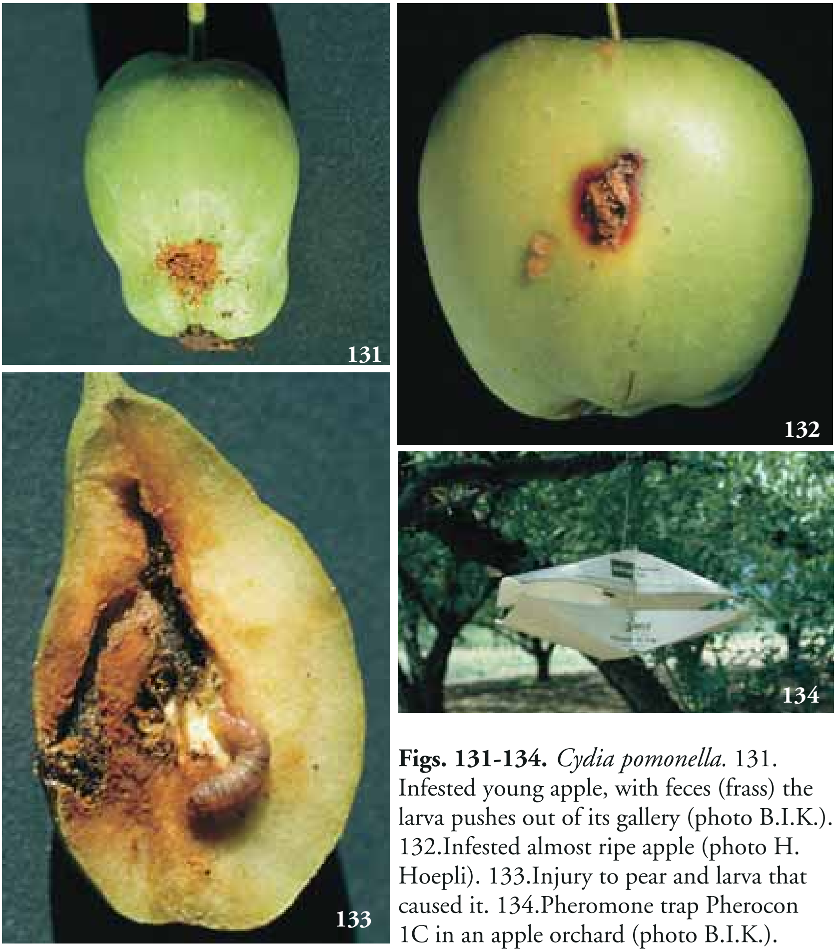
the seed (Silvestri 1943).

The codling moth is generally the most serious insect enemy of apple and pear, and one of the most serious enemies of walnut. Infested fruits (Fig. 133) either drop early, or are unsuitable for the market. The grower should plan to control this insect every year. The



Figs. 131-134. *Cydia pomonella.* 131. Infested young apple, with feces (frass) the larva pushes out of its gallery (photo B.I.K.). 132.Infested almost ripe apple (photo H. Hoepli). 133.Injury to pear and larva that caused it. 134.Pheromone trap Pherocon 1C in an apple orchard (photo B.I.K.).

hazard to the fruit yield depends on the insect's population density, the activity and evolution of the insect population, which depend mainly on climatic factors, and on the abundance of fruits on the trees.

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Control. ***A. Chemical***. It aims at killing the young larvae before they enter the fruits, or even earlier before they hatch from the eggs (i.e. killing the embryons). A winter spraying of the trees and of the places and materials of packing fruit, to kill the fully grown overwintering larvae is usually not effective enough. It is recommended only for trees of relatively old age, that provide abundant refuges on their bark for the larvae to weave their overwintering cocoons, without them having to resort to the soil. Common insecticide for such winter sprays is a winter oil fortified with a proper synthetic insecticide.

Against young larvae in spring and summer, organophosphorous, carbamic or pyrehtroid insecticides, substances inhibiting insect growth and development, and an entomopathogenic virus were used. Among the organophosphorous insecticides were azinphos methyl, chlorpyrifos, diazinon, methidathion, parathion-methyl, phosalone, phosmet, phosphamidon, quinalphos and tetrachlorvinphos. Quinalphos is reported as having also ovicidal action (Kyparissoudas 1990b). Of the carbamates methomyl has larvicidal and embryocidal (ovicidal) action. Pyrethroids that have been used against this insect are bifenthrin, l-cyalothrin, cyfluthrin, fenpropathrin, flucithrinate and fluvalinate. The pyrethroids, except the last one, also prevent hatching, but should not be used more than twice a year (Kyparissoudas 1990b), because they also kill to a great extent useful entomophagous and acarophagous insects and mites. This creates population outbreaks of undesirable insects and especially of phytophagous mites. Consequently, pyrethroids are not suitable for integrated control programs in pome tree orchards, but also in other fruit orchards in general. In addition to larvae, the above organophosphorous, carbamate and pyrethroid insecticides kill also a percentage of the adult moth population. Of the substances inhibitory to insect growth or development, the following have been used against this insect: diflubenzuron, fenoxycarb, hexaflumuron, teflubenzuron and triflumuron. These substances have both ovicidal and larvicidal action, except fenoxycarb which acts on codling moth mainly as an ovicide. The insecticide to prefer is the one which not only kills a substantial percentage of larvae and even eggs of the moth, but also which spares the useful entomophagous and acarophagous arthropods of the orchard.

Voudouris et al. (2009) checked the presence or not of resistance to various insecticide categories (OP, carbamic, pyrethroid, neonicotinoid, IGRs) in populations of the moth from northern, central, and

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southern Greek mainland. In bioassays by topical application to eggs, neonate larvae, last-instar larvae, and diapausing last-instar larvae, they found various levels of resistance to almost all the insecticides tested. The least resistance was recorded to methoxyfenozide and fenoxycarb. Increased MFO activity was positively correlated with resistance to most insecticides tested.

In countries of Europe but also of other continents, the codling moth has been controlled satisfactorily on apple and pear trees with the granulosis virus (GV), formulations of which are on the international market under the commercial names Carpovirusine, Decyde, Granupom, Madex and Virin-Gyap (Deseö-Kovács and Rovesti 1992). This virus is selective. It affects only a few other moths of the Tortricidae, such as *Grapholitha molesta.* The larvae consuming the sprayed plant surface die in approximately 48 hours. Two sprays, 12-15 days apart, are usually needed against each generation of the moth.

The proper time to act against this insect is determined by monitoring the adult population, in combination with the hatching of the first larvae of each generation. Another way is by date, in combination with certain stage of development of the mixed buds and the flowers of host trees.

1. Following the adult population and ovipositions

a) With pheromone traps which are placed in the orchard (Fig. 134), the density of the adult male population is followed. After the first captures of males in the traps, the dusk temperature and relative air humidity are followed. When they exceed 15°C and 60% respectively, regular leaf and fruit samples are taken, to record eggs and hatchings. Based on these records the date of the first spraying is set. It is done with the first hatchings. If the insecticide has also ovicidal action, the spray is applied earlier. The Plant Protection Forecasting Services, which are located in the Regional Centers for Plant Protection and Quality Control, follow the population density of the moth during the critical season and advise the fruit growers when and with which insecticides to spray. In northern Greece, the first spray should be done within the first week from the beginning of “flight” (first captures of adult moths in pheromone traps) if the insecticide has also ovicidal action, and approximately 10 days later if is has only larvicidal action. A second spray is needed approximately 2 weeks later. Against the second generation of the insect one spray is recommended as soon as the captures in pheromone traps are

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substantial, usually in mid-July, and another spray a month later (Kyparissoudas 1990b). Yet, the recommendations of each Center concern a relatively large area. Therefore, it is advisable, those growers that can, to examine their trees themselves, so that they know when oviposition and hatching in their orchard start. Tsitsipis et al. (2007) tried a reduced spray program for codling moth and apple aphids in apple orchards of eastern central Greece. In addition, they followed the population densities of other insect and mite pests of apple trees, as well as the densities of useful insects using proper monitoring methods for each. The codling moth population peaks in 1999 occurred in early June, mid-July and early August, while in 2000 considerable moth activity was observed in late July to early August, and in early September. In 1999 one spray was applied with fenoxycarb, and another three with triflumuron or flufenoxuron. In 2000 only two sprays were applied with either diflubenzuron, fenoxycarb, lufenuron, tebufenozide, teflubenzuron, or triflumuron. Percentages of fruit infestation by codling moth and the aphids *Eriosoma lanigerum* and *Dysaphis plantaginea* at harvest were low, similar to those of orchards with intense insecticide spray programs. Thus, codling moth and the two aphids were controlled with 2-4 insecticidal applications, versus 5-6 in the conventional procedure of apple growers.

b) The time the adults of the overwintering generation appear (emerge from the cocoons) can be determined also by using “pupation bands”. The period apples are harvested, bands of corrugated paper, 7-10 cm wide are placed around the tree trunks, 30-40 cm above ground. The paper should be such as to provide tubelets (furrows, grooves) of a diameter allowing the easy entrance and settling of the codling moth larvae for overwintering. The bands should be fastened so as to be in close contact with the bark. If these bands are placed properly and in time, a high percentage of the larvae searching for an overwintering refuge will settle in the bands. At the end of winter and before bud birst of pome trees, the bands are removed and placed in one or more cages in the orchard, in sites protected from the sun. As soon as the first flowers of apple open the cages are checked daily to see when the first adults come out, and at what rate adult emergence proceeds. Subsequently, adults that emerge out of the corrugated paper bands are caged on apple foliage to observe when hatching of larvae from the eggs they laid begins. When the first larvae hatch, the date of the first spray is set. Pupation bands have been used also

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to determine the time of intervention against the second (summer) generation of the insect. Spraying is recommended a few days after the peak of adult emergence from the caged bands.

c) Another way to determine the time of emergence of the adults of the overwintered generation and the time of hatching of the larvae of the first generation is by the "temperature summation" method. After the termination of the winter diapause, the time for pupation, the duration of the pupal stage and, therefore, the time of emergence of adults, occur when a certain summation of day-degrees is completed above the temperature-threshold for development of each stage. The temperature thresholds, if not already known, should be determined for the given moth population and area. Knowing the thermal constant (K), we find the number of days (y) for the completion of a given stage of the life cycle of the insect, therefore of the first occurrence of the next stage. The formula is K=y (t-a), where "t" is the prevailing temperature and "a" the temperature-threshold for development of the given stage of the insect. Likewise we determine when hatching of the larvae starts.

2. By date (by the calendar)

Against the young larvae of the first generation three sprays, 10-15 days apart, are recommended. The first one is done 10 days after petal fall of the Red Delicious apple, or 20 days after petal fall of pear. Against larvae of the second generation the first spray is done in early July, and more sprays follow, 10-15 days apart, up to mid-August (Anonymous 1973). In the last spray the insecticide should be of short residual action, so that no undesirable residues remain on the fruit at harvest. Spraying by date has the disadvantage of being done irrespective of the existence of a dangerous insect population in the orchard, therefore, more sprays are carried out than under directed control, which is based on the advice given by the Plant Protection Forecasting Services. Consequently, spraying by date reduces to a greater extent the populations of useful arthropods in the orchard and causes more environmental pollution. Where spraying is still carried out by date, selection of the proper insecticide is a must, so as to avoid excessive harm to the useful fauna and the environment in general.

In many parts of Europe, codling moth populations have developed resistance to various classes of insecticides used against them, such as organophosphorous ones, pyrethroids, chitin synthesis inhibitors, and most insect growth regulators. It is unlikely to avoid or delay

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the development of resistance by applying resistance management strategies based exclusively on insecticide alternations (Sauphanor et al. 2002). This is why in France and other countries mixed strategies are recommended (see below).

B. Male annihilation. It has been tested with success in isolated orchards of Switzerland. A dense suspension (slurry) containing the sex pheromone that attracts males, and the synthetic pyrethroid permethrin, was applied in one or two drops on the foliage during the growing season, to attract and kill the males. This resulted in the lack of matings, therefore, the laying of unfertilized eggs. The percentage of infested fruit at harvest was below the tolerable level (for details see Charmillot et al. 1997b).

C. Mating disruprion *(prevention of mating, male confusion).* This method has been successfully tested in a number of countries. In Switzerland, evaporators of the attractive sex pheromone were distributed in the orchards. In most of 40 apple orchards where this was done, no insecticidal spray was needed, and the percentage of infested fruit at harvest was from zero to 1% (Charmillot et al. 1997c). In the Aghia, Larissa area of central Greece, the method was tested in 2010 and 2011 in a 20-hectar apple orchard (Athanassiou et al. 2011). Approximately 500 pheromone evaporators (dispensers) were used per hectar. Captures of male moths in traps and fruit infestation at harvest were negligible, while in control orchards, which received up to 11 insecticidal sprays, fruit infestation was significantly higher. Furthermore, aphid populations in the pheromone-treated orchard were signifficantly lower and the percentage of aphid parasitization higher than in the control orchards. It was concluded that mating disruprion could be used with success against the codling moth in Greece too, in conjunction with additional IPM-based strategies in apple orchards. In Cyprus, the method was tested for the first time in 2002 in three apple orchards. The pheromone evaporators were dispersed once in April, before the appearance of adults of the overwintered generation. The percent of fruit infestation at harvest was slightly lower than in an orchard that received four insecticidal applications (Krambias, 2003). Witzgall et al. (2008) mention that the method by that time was used in 160000 hectares worldwide. They present the pros and cons, including the limitations of the method against the codling moth applied in a number of countries, and suggest continued development to increase the effectiveness of the method. They point out that at high moth population densities the

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method is not effective, and treating adjacent orchards is also needed to avoid mated females coming from those orchards. For effectiveness 100 or more hectares of orchard and a low moth population density are needed. Effective monitoring of the population of the moth and of secondary pests of the apple trees is essential to the success of the method. If moth density exceeds 1000 overwintering larvae per ha, mating disruption to a satisfactory degree is difficult to achieve, owing to low fruit injury tolerance, and should be supplemented with insecticides or the granulosis virus in early season. An advantage is that the effectiveness of the method increases with long term use. Witzgall et al. (2008) also mention that the main mechanisms contributing to mating disruption in the codling moth are considered to be the sensory fatigue of the males caused by the concentration of codlemone in the orchard, and the competition between natural and synthetic sources, i.e. between female moths and codlemone dispensers. When planning to try mating disruption against this or other species of pest moths, it is advisable to consult such reviews on the subject as the one by Cardé and Minks (1995).

D. Release of sterilized populations of the moth *(sterile insect release, sterile male release, sterility method).* It has been applied in other countries with success, and at a reasonable cost. However, it has not been adopted as one of the standard methods of control, because of the required installations and specialized staff. For details of the method, in Greek, see Tzanakakis (1995).

E. Other measures. As a supplementary measure against the codling moth the placement on the trunks of pupation bands (see above) with or without an insecticide and their timely destruction of the larvae or pupae they contain. The timely collection of infested fruits and offering them as feed to farm animals, is another supplementary measure.

F. Mixed strategies. In France, in high codling moth risk areas or orchards, insecticides are applied in high frequency during the peak hatching of larvae of each generation. At low risk periods and throughout the season in areas or orchards with low risk or with susceptible moth populations, alternative control measures or reduced frequency of more selective insecticides are recommended. The best long-term resistance management strategy, according to Sauphanor et al. (2002) is expected to be the application of mating disruption or the granulosis virus together with limited use of insecticides. In

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Switzerland, where resistance has also developed to various classes of insecticides, mating disruption and the granulosis virus are the most appropriate alternatives to chemical control (Charmillot and Pasquier 2002). In Italy too, resistance to insecticides has been detected in two of the main apple-growing regions, Trentino and Emilia Romagna. In Trentino, the wide application of mating disruption allowed the successful management of resistance to pesticides. Also in Emilia Romagna mating disruption plus the use of the granulosis virus is the main tactic proposed for resistance management. Also new insecticides such as Spinosad and triacloprid and ovo-larvicidal IGRs could be introduced in IPM programs, according to Ioriatti et al. (2002). Caution is necessary in pear orchards, where insecticides may adversely affect natural enemies of pear psylla. In South Africa, the detection of a very high level of codling moth resistance to azinphos-methyl and to some pyrethroids, necessitated a restructuring of the chemical control strategy. In a block of apple orchards, after 6 years of mating disruption combined when necessary with insecticide sprays, the number of necessary sprays was reduced by almost 90%, and fruit infestation to only 0.02% (Blomefield 2002).

Hedya nubiferana **Haw.** *(H. variegana, H. tripunctata, H. cynosbatella, Argyroploce variegana)* **(Lepidoptera, Tortricidae)**

Adult. It has a wing span of 17-21 and a length of approximately 10 mm. The forewings in their basal part are brown with many disperse silver-blue spots, and in their apical part white, with a few somewhat dark spots. The demarcation line between the basal dark and the apical light-colored part begins at the middle of the front wing margin, is directed obliquely towards the apex up to 2/3 of the width of the wing, then is curved and ends almost vertically to the posterior wing margin near the anal corner. The white part becomes darker at its apex, because of irregular light-brown spots. The hindwings are uniformly light-brown (Bovey 1966). Adults which we believe belong to this species, resulting from larvae we collected on quince leaves in 1980 on the Aristotelian University farm near Thessaloniki, had the basal part of their forewings definitely darker than given above. It resembled rather to that given by Bovey for *Hedya pruniana.*

Egg. It is flat, 0.8-0.9 x 0.6-0.7 mm. The chorion is transparent, iridescent, with a slight net-like pattern on the surface.

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Larva. The body is oil-green or dark green, and 18-20 mm long when the larva is fully grown. The head, the prothoracic shield and the anal shield are dark brown or black. The thoracic legs are black, and the prolegs sclerotized and brown on the sides. Each proleg has 40 hooks. Even in the early instars the larva has big black hair-bearing tubercles on the dorsum (Bovey 1966).

Pupa. It is 8-10 mm long, brown-black to shiny black. At the tip of the abdomen there are 4 pairs of hook-shaped hairs, 2 of which are proximal to the rest, and on either side of the anal slit.

Geographic distribution. Almost the whole Europe, from the southernmost to almost the arctic circle, including Greece, Turkey, Syria, Israel, and Caucasus, as well as parts of North America.

Host trees. It is a polyphagous species, infesting species of Rosaceae and also of the genera *Sorbus, Salix, Quercus, Betula, Fraxinus* and *Ribes.* According to Bovey (1966) it injures the foliage mainly of apple, less of almond, and even less and less often of other trees and shrubs. According to Isaakides (1936a) it infested apricot trees in Attica, without causing serious damage. In the Thessaloniki area we found it mainly on leaves of quince and less so of plum and cherry (Tzanakakis and Prophetou-Athanasiadou unpublished data).

Life history and damage. It has one generation per year. According to Bovey (1966), its life history in central Europe is the following: It overwinters as a young larva in sheltered sites on the tree, usually in bark fissures. The larva becomes active in March-April, when the buds of the apple tree are in stages of development from C to F (of Fleckinger), i.e. from green tip to prebloom. It enters in the developing buds where it unites with silk threads the tips of young leaves around the closed flowers and feeds preferably on the flowers. It can destroy 3-4 flowers in a week. Subsequently it moves to a second or third inflorescence where it destroys closed flowers and leaves after forming a nest around them. It is a typical leaf-roller. It completes growth in May and pupates in a loose cocoon between united leaves. The adults emerge in 14-25 days and are seen in the orchards from mid-June to late August. The eggs are laid singly or in groups of 2-4 on the lower leaf surface. Hatching takes place in 10 days. The neonate larva forms a tube-like nest usually along the midrib of the leaf, and eats the lower epidermis and leaf parenchyma without injuring the upper-leaf epidermis. The larva may also be found between two leaves or between a leaf and a fruit which it unites with silk threads. In the last

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case, it may erode the fruit superficially, thus lowering its commercial value, or also favoring infection by pathogenic microorganisms. This activity of young larvae continues until September-October. Shortly before leaf fall, the larvae which then are 2-4 mm long, abandon the leaves and each searches for an overwintering site.

Damage occurs in two periods: in spring when flowers and tender leaves are eaten and normal development of buds and shoots is affected, and in summer and autumn when the fruits are eroded superficially.

Control. Proper seasons for insecticidal applications are considered the following: 1) Winter, using an emulsion of winter oil with a synthetic insecticide, or with another penetrating spray. 2) Spring, shortly before the development of buds, with an organophosphorous insecticide combined with a summer oil. 3) At the beginning of bud development, with a contact insecticide or a stomach one, preferably organophosphorous. 4) Summer, when 70% of larvae have hatched from the eggs, with an organophosphorous insecticide (Bovey 1966).

Laspeyresia pyrivora **Danilevsky** *(L. dannehli)* **(Lepidoptera, Tortricidae)**, comm. **pear carpocapsa**

Adult. It resembles so much in shape and color the codling moth, *Cydia pomonella,* that only an experienced specialist can distinguish one species from the other. Only comparison of the male genitalia can distinguish the species with certainty. The speculum usually has 4 black lines. The hind wings do not have at the cubitus the forceps-like group of long hairs which characterize the codling moth.

Larva. The morphology of the egg and larva distinguish rather easily this species from its relative *C. pomonella,* which also infests pears. The fully grown larva is whitish, with a black or brown-black head, and is 22-23 mm long. The last abdominal prolegs have each 5-7 hooks.

Geographic distribution. According to Bovey (1966), its presence has been proven in Crete, Sicily, Sardinia, south Tyrol, Austria, Ukraine including Crimea, Caucasus, Transcaucasia, and northern Syria. It most likely occurs also in some other regions, where its presence has not been recorded because of its great similarity to *C. pomonella.*

Host trees. Cultivated and wild pear, i.e. *Pyrus communis* and *P.*

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amygdaliformis.

Life history and damage. According to Bovey (1966), the relatively limited data on this species' life history come from "southern Ukraine" (probably Crimea), the Tyrol and Austria. According to those data, this species completes one generation per year. It overwinters as a fully grown larva in a cocoon at a small depth in the soil underneath the host trees. In Austria it pupates in the second decade of May and the adults appear usually in mid- to late June. They are active for approximately one month. The female lays its 20-30 eggs singly on the fruits. Under high population densities, more than one eggs per fruit can be found, but only one larva will complete growth in a fruit. The other larvae will be victims of cannibalism. Incubation lasts 1-3 weeks, depending on temperature (Bovey 1966).

The neonate larva enters directly the fruit, piercing the chorion which is in touch with the fruit. It directs its gallery towards the fruit center where it settles and eats the seeds. During the larva's stay inside the fruit there are no characteristic external signs of its presence, except the egg's chorion which remains on the fruit for some time. This makes difficult the discarding of infested pears during harvest, thus favoring the spread of the species with the transport of supposedly healthy pears. When infestation starts the pears are big enough, so one fruit is sufficient for the larva to complete growth. Upon completion of its growth, the larva opens a 1-2-mm exit hole and drops to the soil to overwinter.

The exit hole facilitates the entrance of microorganisms, mainly fungi, which cause rotting of the fruit. In many countries *L. pyrivora* is the most serious insect pest of pears. In other countries it is less harmful to pears than the codling moth, with which it coexists in the same orchards. In Greece, where this insect unquestionably occurs in addition to Crete, it is necessary to determine its frequency of occurrence in pears in comparison with codling moth. Given the differences in voltinism between the two species, such determination may help avoiding unnecessary insecticidal applications on one hand, and misinterpretation of moth captures in pheromone traps on the other, because of the great similarity of the adults of the two species.

Differences in the susceptibility to this insect between certain pear cultivars have been recorded in Austria. Thus, Beurre Bosc, Bon Cretien William, Louise Bonne, and Clairgeau were heavily infested, Beurre Gellert and Clapp's Favorite little infested, and neighboring trees of Bergamotte Esperen and Poire Cure not infested at all.

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Control. The neonate larva enters the pear directly, without walking on the fruit surface. Therefore, intervention should be ditected against the adult moths early, before they oviposit. If spraying was delayed and oviposition has progressed, the insecticide should have an in-depth action, i.e. to kill the young larva before it has bored deep in the fruit. Such insecticides with some in-depth action are parathion and certain other organophosphorous ones. According to Bovey (1966), by following the progress of oviposition and incubation on the pears we can determine the right day to spray, so as to kill the young larvae before they go deep in the fruit.

***Saturnia pavonia* L. (*Eudia pavonia*) (Lepidoptera, Saturniidae),** comm. **lesser emperor moth**

Adult. It resembles considerably *S. pyri* (see below), in color, shape, and eye-shaped spots of wings, but it is definitely smaller, having a wing span of 50-65 mm. According to Della Beffa (1961) the coloration differs between the sexes. The male is brown-yellow-reddish, while the female is grey with sometimes a yellowish or pinkish hue. The forewings have at their apex a small oblong black spot, and behind it a red one. The zigzag line in both the fore- and hindwings is almost parallel to the external margin of the wings. According to Isaakides (1936a) the wings in the male have the coloration of rust, and the hindwings are yellow-orange in the middle.

Larva. The first and second instars are black, with black setae. The third instar is black with a flesh-colored band on the sides, and brown setiferous tubercles. The fourth instar is green, with a black cross band in the middle of each body segment, and with yellow tubercles bearing black setae. The last (5th) instar is 40 mm long, and differs from the 4th one in having orange tubercles bearing black spines.

Host trees. Pear, apple, plum, *Carpinus* sp., *Ostrya* sp., *Crataegus* sp., *Rubus* sp., elms, oaks, willows, and other.

Life history and damage. It is found in the whole of Europe. It has one generation per year and overwinters as pupa. Its life history is similar to that of *S. pyri* (below). The eggs are laid in large groups around twigs of host trees. These egg masses often cover 3 cm of the length of twigs. It usually does not cause considerable damage. In Italy, according to Della Beffa (1961), it occurred more often than *S. pyri.*

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Saturnia pyri Schiffermueller (Lepidoptera, Saturniidae), comm. **greater emperor moth, Viennese emperor moth**

Adult. It is the largest moth in Europe, having a body length of 40-45, a width of 12-15, and a wing span of 120-160 mm. The female is usually larger than the male. The wings are especially large and the head relatively small. Its appearance is characteristic, and in combination with its size, the adult can be easily identified (Fig. 135).

Egg. White to pink, and according to some authors greenish, 2 x 1.5 mm. In shape it resembles a small seed of sorghum (Fig. 136).

Larva. In every segment of its body it has 6 characteristic hair-bearing tubercles. Every such tubercle has starwise 5-9 spines and a long seta which is swollen at its apex. The fully grown larva is light green or green-yellow, with cylindrical hair-bearing tubercles and 100-120 mm long. (Fig. 137). Therefore, the larva is also one of the largest caterpillars we find in Greece.

Host trees. Pear, apple, elm (*Ulmus*) and other trees.

Life history and damage. It completes one generation per year. It overwinters as pupa in a cocoon on the trees or other suitable sites.

Figs. 135-137. *Saturnia pyri.* 135.Adult. 136.Eggs on a leaf. 137.Larva (photo B.I.K.).

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It becomes adult in spring. It attaches its eggs, in small or large groups, on twigs and branches of host trees (Fig. 136). The larvae are phyllophagous. After consuming a number of leaves, they complete growth in June-July. In the Micra area, near Thessanoniki, eggs and young larvae were observed on pear in late May 1981, and fully grown larvae, ready to pupate, in late June-early July, not only on pear, but also on apricot and cherry trees (B.I. Katsoyannos, unpublished data). Substantial damage by this insect is rare, because its populations are maintained at low densities, because of the action of entomophagous insects and other animals.

Control. In the rare cases when considered necessary, a spray with a stomach or contact insecticide can be applied. When the trees are few, collection of those big larvae by hand is easy.

Euproctis chrysorrhoea **(L.)** *(Atraxia chrysorrhoea, Liparis chrysorrhoea, Nygmia phaeorrhoea)* **(Lepidoptera, Lymantriidae)**, comm. **brown-tail moth**

Adult. It is totally snow white, except the four last abdominal segments which are covered by dense golden-brown shiny hairs. These hairs are longer and more abundant in the female (Fig. 138). The wing span is 31-45 mm (Isaakides 1936a). The female is larger and has a more bulky abdomen than the male. For photos of adult and larva see Avtzis et al. (2013).

Egg. Spherical, brownish or yellow. The eggs, 200-400 together, are laid in oblong masses measuring 30 x 4-5 mm, on the underside of leaves, and less often on twigs. The egg mass is covered with dense golden-brown hairs from the maternal abdomen.

Larva. It is hairy. The first-instar larva is pale yellow. That of later instars is grey-brown, almost black, with 2 red-brown lines along the dorsum. In each body segment there are hair-bearing tubercles, which form lines along the body. The tubercles of the two medial dorsal lines have spine-like hairs, and those of the rest whitish hairs. On the dorsum of the 6th and 7th abdominal segments there is a red or orange tubercle. The fully grown larva is approximately 35 mm long (Isaakides 1936a). The larvae have urticating poisonous hairs that can cause dermatitis or even more serious symptoms to sensitive persons (see *Lymantria dispar* below, and *Thaumetopoea pityocampa).*

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Figs. 138-139. *Euproctis chrysorrhoea.* 138.Left female, right male. 139.Larval nest-refuge of loose fibers on a pear tree (photo B.I.K.).

Host trees. It is a polyphagous species. It infests broad-leaf trees and shrubs. Among the preferred hosts are reported pear, apple, stonefruit trees, chestnut, oak, elm, *Fagus silvatica,* and *Arbutus* sp. In the Firenze area of Italy, cherry and plum have been reported to be damaged more than almond, apricot, pear and apple, and chestnut and hazelnut more than oak (R. Sta. Entomol. Agr. Firenze 1924).

Life history and damage. It completes one generation per year. It overwinters as a larva, probably of the third instar. In autumn, many larvae together weave a nest at the tip or near the tip of a shoot of the year. The nest is light grey, consists of a dense tissue of fibers and leaves, contains approximately 250 larvae, and measures 5-10 x 3-7 cm (Isaakides 1936a). The larvae are leaf-eaters and in early instars are gregarious. In spring, with the start of new tree growth, they consume developing buds, leaves and flowers. They construct shelters of loose silk threads and leaves to protect themselves (Fig. 139). According to Isaakides (1936a) they complete growth and pupate in May to early June in a cocoon they weave in shrubs or other plants near the base of infested trees. The cocoon is surrounded by dry leaves that the larva connects with silk threads. Depending on the region, the adults are formed in June and July, mate and oviposit. The young larvae hatch 2-3 weeks later. In September they construct the overwintering nest.

Under high population densities the damage may be serious, the larvae being able to completely defoliate trees, and by eating the flowers, they may annihilate fruit production of the year, as observed in the past in the area of Firenze, Italy (R. Sta. Entomol. Agr. Firenze 1924).

Control. Where overwintering nests are seen in an alarming

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number, a spray is recommended when the new growth starts. Also, an insecticide is applied if the larval population in summer is dense. It can be a contact or a stomach insecticide. The insecticide should be selective, so as to allow survival of effective natural enemies of the moth. Avtzis et al. (2013) report as effective formulations of *Bacillus thuringiensis* and inhibitors of chitin synthesis. If the infested trees are few, removal and burning of the overwintering nests at pruning time is another measure to be taken.

Lymantria dispar **(L.)** *(Porthetria dispar, Liparis dispar)* **(Lepidoptera, Lymantriidae)**, comm. **gypsy moth, lymantria**

Adult. The sexes differ in appearance, hence the specific name *dispar* (disparate, dissimilar). The male wingspan is 40-42 and the female one 45-75 mm. The male forewings are light brown and in certain populations dark brown. The hindwings are ochre brownish, darker near their outer border (termen). The abdomen is relatively slender (Isaakides 1936a) (Fig. 140). The female is considerably larger than the male. Its forewings are whitish, and have 4 fine, wavy, brown cross lines. The hindwings are also whitish and have a fine brown line near the termen. Along the termem, fore- and hindwings have dark brown spots. The abdomen is wide and has abundant long brown shiny hairs (Isaakides 1936a).

Egg. At first it is pink, and later green. Many eggs, 200-500, are united in a mass 20-25 mm long and are covered with a dense layer of light brown hairs from the maternal abdomen. The eggs are placed on the trunk and limbs of host trees. When the adult population is dense, egg masses can be seen also on stones near the trunk.

Larva. The young larva is dark brown or red brown. In later instars the head is yellowish with two longitudinal black lines. In every body segment there are 6 voluminous tubercles, each of which bears a tuft of brown hairs. On the first 5 segments (the 3 thoracic and 2 first abdominal) the two median dorsal tubercles are blue, whereas in the following 6 abdominal segments they are dark red or red. The final body length is 60-70 mm (Fig. 141).

Pupa. Inside a coccoon on branches, trunk, or on nearby stones when the population is dense.

Host trees. It is exteremely polyphagous. The larvae feed on most broad-leaved forest and fruit trees, as well as on many ornamental

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Figs. 140-141. *Lymantria dispar*. 140. Female with closed, and male with expanded wings. 141.Larva on a leaf (photo B.I.K.).

trees and shrubs. Among them are chestnut, hazelnut, pear, apple, plum, elm, willow, poplars and oaks.

Life history and damage. It has one generation per year. It overwinters in the egg stage. The eggs are deposited in masses on the bark of trees. The larvae hatch in spring, when the new growth of broad-leaf trees begins, usually in April-May. They are leaf-eaters. They disperse on the foliage and eat the leaf lamina, leaving as a rule only the midvein. After defoliating a branch or a tree, they go to the neighboring one. They complete growth and pupate in June. The adults are formed in July and oviposit in July-August. In the Thessaloniki area, fully grown larvae were observed in early June, pupation in June, and adult emergence mid-June to late June (B.I. Katsoyannos, personal observations). The female either does not fly, or flies at a very short distance. Therefore, the female does not contribute substantially to the dispersion or the spread of this species. Dispersion is by young larvae which the wind takes away, especially when they are hanging at the end of a silk thread they secrete to this end, and also by larvae of various instars which walk in search of food.

This species has population outbreaks certain years. These outbreaks involve relatively large areas and during them the defoliation of fruit trees, especially those near forests, may be serious. In Europe, as a rule, natural enemies keep this insect to bearable population densities. The hairy larvae have poisonous urticating hairs which contain histamine and can cause dermatitis and other more serious reactions to sensitive persons, similar to those caused by larvae of the pine processionary caterpillar *(Thaumetopoea*

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pityocampa). All larval instars of *L. dispar* contain histamine. For ways of immediate treatment of such cases see Goddard (1996).

Control. When necessary, a spray with a contact insecticide or a stomach one will kill the larvae. A selective one should be preferred, so as not to annihilate the effective natural ememies of this moth. During a period of an outbreak in Halkidiki, northern Greece, a formulation of *Bacillus thuringiensis* var. Kurstaki/Aizawai was applied once by air in stripes 200m wide of forest land, of a total 1000 hectares. The results were considered satisfactory with respect to killing the moth population and allowing the survival and activity of two hymenopterous parasitoids and the predatory beetle *Calosoma sycophanta* (Kalapanida-Kantartzi and Zartaloudis 2005).

***Hoplocampa brevis* Klug (Hymenoptera, Tenthredinidae)**, comm. **pear sawfly, pear hoplocampa**

Adult. It is 4-5 mm long and has a wing span of 10 mm. The head is brown-red or light brown, the antennae light brown, the thorax brown with black spots, the abdomen black and the legs yellow.

Larva. It has green-yellow color and a final length of 10 mm. It smells like a bedbug.

Host trees. Pear. No other host tree is known.

Life history and damage. It has one generation per year. It overwinters as a grown larva in a cocoon in the soil. The adults appear early in spring (mid-March to early April), when the pear tree is in bloom.They feed on nectar and pollen, mate and oviposit before the end of the plooming period of the host tree. In some countries the males are rare, and it is thought that reproduction is parthenogenetic. Using its saw-like opipositor, the female makes a slit in the flower calyx and introduces an egg. As a rule, it lays one egg per flower. If more than one eggs are laid in the same flower, only one larva survives and develops. The young larva bores a perimetric gallery in the surface layers of the small fruit. This gallery, after having circumvented the calyx, usually ends near the point it started. Subsequently the larva molts to second instar and is headed to the center of the young fruit which it consumes. Most authors state that the larva feeds and develops in only one fruitlet. Anagnostopoulos (1939) mentions that, to complete its growth, the larva may attack more than one fruitlets. In this case, the larva abandons the first fruitlet and enters another,

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Fig. 142, 143. 142. Young pears infested by *Hoplocampa brevis.* The dark points are exit holes of grown larvae (photo B.I.K.). 143. White color trap for capturing adult hoplocampas (photo B.I.K.).

of which it eats the central part and the seeds. It completes growth in the second fruitlet. More rarely it may infest a third fruitlet. The grown larva opens an exit hole (Fig. 142), drops to the soil and weaves a cocoon at a small depth, where it overwinters, and pupates in late winter.

Infested fruits have deformations, dark spots and finally drop (Fig. 142). Infestation may cause also flower drop. Damage to the crop is usually not great. However, it may be considerable when the sawfly population is not limited by the action of natural enemies or by insecticides that are used against other insect enemies of pear (aphids, psylla, scale insects).

Control. Usually one insecticidal spray, immediately after bloom is sufficient when the insect population reaches the intervention threshold (see *Hoplocampa testudinea).* To follow population density, in Switzerland and other countries, white color sticky traps are used (Fig. 143). Certain authors recommend one more spray before bloom. In older times an autumn or winter ploughing was recommended to reduce the overwintering larval population in the soil.

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Hoplocampa testudinea Klug (Hymenoptera, Tenthredinidae), comm. **apple sawfly, apple hoplocampa**

The adult is 6-7 mm long. The head is yellow or light brown with black spots, the thorax yellow with the mesonotum and metanotum brown-black, the abdomen dorsally and ventrally black and laterally yellow, and the legs yellow (Fig. 144). The fully grown larva is 12 mm long. This insect has one generation per year. It infests the flowers and young fruits of apple in a way similar to that *H. brevis* infests the flowers and fruitlets of pear (Fig. 145). The superficial gallery of the young larva causes to the young fruit a characteristic long scar, often sinuous (Fig. 146).

In orchards where the infestation in the previous year was considerable, it is recommended to follow the density of the insect's population with white sticky traps (Fig. 143), and to spray when the captures reach the intervention threshold. Charmillot et al. (1997a) recommend one spray immediately after bloom, if flowering is not abundant and the captures exceed 20-30 adults per trap from the beginning to the end of bloom. As suitable insecticides they recommend chlorpyrifos-methyl, diazinon, quassia and thiocyclam.

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Figs. 144-146. *Hoplocampa testudinea.* 144.Adult on a flower. 145.Infested small apples (codlings) (photo H. Hoepli). 146.Distortion of an apple and scar of the superficial larval gallery (photo U. Remund).

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Insects of stone fruit trees

Isoptera (termites)

- ■ *Kalotermes flavicollis* F., Kalotermitidae

Homoptera

- *Empoasca decedens* Paoli, Jassidae
- *Psylla pruni* Scopoli, Psyllidae
- ■ *Parabemisia myricae* (Kuwana), Aleyrodidae
- ■ *Metcalfa pruinosa* (Say), Flatidae

Aphids

- *Anuraphis persicae* Boyer de Fonscolombe, Aphididae
- *Aphis gossypii* Glover, Aphididae
- *Brachycaudus amygdalinus* (Schouteden), Aphididae
- *Brachycaudus helichrysi* (Kaltenbach), Aphididae
- *Brachycaudus persicae* (Sulzer), Aphididae
- ■ *Hyalopterus amygdali* (Blanchard), Aphididae
- ■ *Hyalopterus pruni* (Geoffroy), Aphididae
- *Myzus cerasi* (F.), Aphididae
- ■ *Myzus persicae* (Sulzer), Aphididae
- *Phorodon pruni* Ferrari, Aphididae
- *Pterochloroides persicae* (Cholodkovsky), Lachnidae

Coccoidea (scale insects)

- ■ *Aspidiotus nerii* (ïuché), Diaspididae
- *Aulacaspis rosae* (Bouché), Diaspididae
- ■ *Lepidosaphes ulmi* (L.), Diaspididae
- ■ *Parlatoria oleae* (Colvée), Diaspididae
- ■ *Pseudaulacaspis pentagona* (Targioni-Tozzetti), Diaspididae
- ■ *Quadraspidiotus perniciosus* (Comstock), Diaspididae
- *Quadraspidiotus piri* Licht., Diaspididae
- *Eulecanium corni* L., Coccidae
- *Palaeolecanium bituberculatum* (Targioni-Tozzetti), Coccidae
- ■ *Saissetia oleae* (Bernard), Coccidae
- ■ *Sphaerolecanium prunastri* (Boyer de Fonscolombe), Coccidae
- *Pseudococcus viburni* (Signoret), Pseudococcidae

Hemiptera

- ■ *Calocoris fulvomaculatus* De Geer, Miridae
- ■ *Calocoris norvegicus* Gmelin, Miridae
- ■ *Calocoris trivialis* Costa, Miridae
- *Eurydema ornatum* L., Pentatomidae
- ■ *Monosteira unicostata* Mulsant and Rey, Tingidae
- ■ *Stephanitis pyri* (F.), Tingidae

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Thysanoptera (thrips)

- *Ceratothrips discolor* Karny, Thripidae
- *Chirothrips manicatus* Haliday, Thripidae
- ■ *Frankliniella intonsa* (Trybom), Thripidae
- ■ *Frankliniella occidentalis* (Pergande), Thripidae
- *Limothrips cerealium* Haliday, Thripidae
- *Taeniothrips inconsequens* (Uzel), Thripidae
- *Taeniothrips meridionalis meridionalis* Priesner, Thripidae
- *Taeniothrips vulgatissimus* (Haliday), Thripidae
- *Thrips major* Uzel, Thripidae
- *Thrips tabaci* Lindeman, Thripidae

Coleoptera (beetles)

- *Cetonia aurata* (L.), Scarabaeidae
- ■ *Epicometis hirta* (Poda), Scarabaeidae
- ■ *Aurigena unicolor* Olivier, Buprestidae
- ■ *Capnodis carbonaria* Klug, Buprestidae
- ■ *Capnodis porosa* Klug, Buprestidae
- ■ *Capnodis tenebricosa* Olivier, Buprestidae
- ■ *Capnodis tenebrionis* L., Buprestidae
- ■ *Ptosima flavoguttata* Ill., Buprestidae
- *Ptosima undecimmaculata* Hbst. Buprestidae
- ■ *Sinoxylon sexdentatum* Olivier, Bostrychidae
- ■ *Teratolytta dives* Brullé, Meloidae
- *Cerambyx dux* Faldermann, Cerambycidae
- *Cerambyx scopolii* Fuessly (*C. cerdo*), Cerambycidae
- *Cerambyx velutinus* Brullé, Cerambycidae
- *Mesosa curculionoides* L., Cerambycidae
- *Nathrius brevipennis* (Mulsant), Cerambycidae
- *Prionus coriarius* L., Cerambycidae
- *Rhopalopus clavipes* F., Cerambycidae
- *Saperda scalaris* L., Cerambycidae
- *Clytra atraphaxidis* Laicharting, Chrysomelidae
- *Labidostomis humeralis* Scheider, Chrysomelidae
- *Lachnaea sexpunctata* Scopoli, Chrysomelidae
- ■ *Involvulus cupreus* (L.), Attelabidae
- ■ *Rhynchites auratus* Scopoli, Attelabidae
- ■ *Rhynchites aequatus* L., Attelabidae
- ■ *Rhynchites bacchus* (L.), Attelabidae
- ■ *Rhynchites smyrnensis,* Debr., Attelabidae
- ■ *Rhynchites zaitzevi* Kies., Attelabidae
- ■ *Anthonomus amygdali* Hustache (*A. ornatus*), Curculionidae
- ■ *Anthonomus cyprius* Mshl., Curculionidae
- ■ *Anthonomus gemmicola* Ter Minacian, Curculionidae
- ■ *Anthonomus gentilis* Faust., Curculionidae
- ■ *Anthonomus ornatoides* Reitter, Curculionidae
- *Anthonomus rectirostris* L., Curculionidae
- ■ *Curculio (Balaninus) nucum* (L.), Curculionidae

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Cycloderes fritillum Panzer, Curculionidae
Magdalis barbicornis Latreille, Curculionidae
Magdalis ruficornis L., Curculionidae
Peritelus spaeroides Germar, Curculionidae
Phyllobius oblongus (L.), Curculionidae
Phyllobius pyri (L.), Curculionidae
Polydrosus armipes Brullé, Curculionidae
■ *Xyleborus (Anisandrus) dispar* F., Scolytidae
■ *Scolytus amygdali* Guérin, Scolytidae
■ *Scolytus mediterraneus* Eggers, Scolytidae
■ *Scolytus rugulosus* Mueller, Scolytidae

Diptera

■ *Contarinia pruniflorum* Coutin and Rambier, Cecidomyiidae
Odinadiplosis amygdali (Anagnostopoulos), Cecidomyiidae
■ *Ceratitis capitata* (Wiedemann), Tephritidae
■ *Rhagoletis cerasi* L., Tephritidae

Lepidoptera

Stigmella prunetorum Stainton, Nepticulidae
■ *Leucoptera malifoliella* (O. G. Costa), Lyonetiidae
■ *Lyonetia cherkella* (L.), Lyonetiidae
■ *Phyllonorycter blancardella* (F.), Gracillariidae
■ *Phyllonorycter cerasicolella* (Herrich-Schaeffer), Gracillariidae
■ *Phyllonorycter corylifoliella* (Haw.), Gracillariidae
■ *Synanthedon myopiformis* Borkhausen, Sesiidae
■ *Yponomeuta evonymellus* L., Yponomeutidae
■ *Yponomeuta padellus* (L.), Yponomeutidae
■ *Anarsia lineatella* Zeller, Gelechiidae
Recurvaria nanella (Hübner), Gelechiidae
■ *Cossus cossus* L., Cossidae
■ *Zeuzera pyrina* (L.), Cossidae
Acleris variegana Denis & Schiffermueller, Tortricidae
■ *Adoxophyes orana* Fischer von Rösslerstamm, Tortricidae
■ *Archips rosanus* L., Tortricidae
Argyresthia ephyppella F., Tortricidae
■ *Cydia pomonella* (L.), Tortricidae
■ *Grapholitha funebrana* Treitschke, Tortricidae
■ *Grapholitha molesta* (Busck), Tortricidae
■ *Hedia pruniana* Hübner, Tortricidae
■ *Cadra cautella* (Walker), Pyralidae
■ *Ectomyelois ceratoniae* (Zeller), Pyralidae
■ *Euzophera bigella* Zeller, Pyralidae
■ *Yponomeuta evonymellus* L., Yponomeutidae
■ *Yponomeuta padellus* L., Yponomeutidae
Epicnaptera tremulifolia (Hübner), Lasiocampidae
Eriogaster lanestris L., Lasiocampidae
Malacosoma neustria L., Lasiocampidae

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Odonestis pruni (L.), Lasiocampidae
- *Saturnia pavonia* L., Saturniidae
- *Saturnia pyri* Schiffermueller, Saturniidae
- *Hyphantria cunea* (Drury), Arctiidae
- *Diloba caeruleocephala* (L.), Noctuidae
- *Euproctis chrysorrhoea* (L.), Lymantriidae

Orgyia antiqua L., Lymantriidae
- *Lymantria dispar* (L.), Lymantriidae
- *Aporia crataegi* (L.), Pieridae
- *Iphiclides podalirius* L., Papilionidae
- *Vanessa polychloros* (L.), Nymphalidae

Hymenoptera
- *Neurotoma nemoralis* L., Pamphiliidae
- *Arge melanochroa* Gmelin, Argidae
- *Arge proxima* André, Argidae
- *Arge scita,* Argidae
- *Palaeocimbex quadrimaculata* (O. F. Mueller), Cimbicidae
- *Caliroa cerasi* (L.), Tenthredinidae
- *Hoplocampa flava* L., Tenthredinidae
- *Hoplocampa minuta* Christ., Tenthredinidae
- *Hoplocampa rutilicornis* Klug, Tenthredinidae
- *Eurytoma amygdali* Enderlein, Eurytomidae
- *Eurytoma schreineri* Schreiner, Eurytomidae

Hyalopterus pruni **(Geoffroy)** *(H. arundinis)* **(Homoptera, Aphididae)**, comm. **mealy plum aphid, mealy aphid of stone fruits**

Adult. The winged adult has dark brown to black head and thorax, and light brown abdomen. The wingless one has a long light green body with dark green stripes and a waxy, like dust, smear (Fig. 147).

The antennae are shorter than the body, the siphons are dark grey to black, short and slender, and the cauda green, conical, and longer than the siphons (Bodenheimer and Swirski 1957).

Host plants. Main hosts are stone fruit trees (*Prunus* spp.) such as almond, apricot, peach, plum, and secondary hosts mainly wild reeds (*Phragmites communis*) and less often common reeds (*Arundo donax*).

Life history and damage. It overwinters usually as an egg on stone fruit trees. After a number of spring generations, winged adults migrate to wild reeds and reeds, where summer generations follow. In autumn, winged individuals return to *Prunus* where sexual forms

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Fig. 147. *Hyalopterous pruni.* Many wingless individuals, and their wax secretions on the undersurface of almond leaves (photo B.I.K.).

are produced that lay the winter eggs. According to Isaakides (1936a) this aphid infests mainly the lower leaf surface, without causing curling of the lamina (Fig. 147), but may cause early leaf and fruit drop. According to Anagnostopoulos (1939) and Bodenheimer and Swirski (1957), it causes leaf curling and necrosis, as well as atrophy, cracking and falling of fruits when fruits are also infested. For control measures see Aphididae. Approximately similar is the life history of the relative and morphologically similar *H. amygdali.*

Myzus persicae **(Sulzer) (Homoptera, Aphididae)**, comm. **green peach aphid**

Adult. The apterous parthenogenetic viviparous female has a relatively slender body, 1.5-2.5 mm long, which is green, yello-green, yellow, or pink (Figs. 148- 149). Sometimes it has along the dorsum brown stripes. The siphons are slender and long, 0.4 mm, but do not exceed the tip of the cauda. The cauda is oblong, 0.2 mm long, and bears 3 pairs of setae.

Host plants. The green peach aphid is extermely polyphagous. It infests more than 400 species of plants. Of cultivated plants it infests species of Rosaceae, Rutaceae, Solanaceae, Malvaceae, Compositae, Chenopodiaceae, Umbelliferae, Papilionaceae, Cruciferae. The winter eggs are laid mainly on peach, and secondarily on other stonefruit trees (apricot, plum, cherry, almond), which are the primary hosts of this aphid. In addition to many fruit trees, this aphid infests many

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Figs. 148-151. *Myzus persicae.* 148.Two wingless individuals on the undersurface of a leaf (photo N.T. Papadopoulos). 149.Colony on a tangerine leaf (Melia 1982). 150.Colony on tender peach leaves (photo B.I.K.). 151.Infestation and deformation of apical leaves of peach (photo S. Katerinis).

herbaceous cultivated plants, such as tobacco, potato, tomato, lettuce, wheat, carrot, broad bean and cabbage.

Life history and damage. It completes more than 5 generations per year. In regions with relatively cold winters, such as Europe, it overwinters as winter egg on the bark of primary hosts (peach, or other stone fruit tree). The winter eggs, usually 4-6 per female, are laid on buds or in fissures and other hollow sites of rough bark. In late winter to early spring, from the

Fig. 152. Sooty mold on peaches due to honeydew excreted by aphids (photo B.I.K.).

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winter eggs hatch apterous parthenogenetic females, the fundatrices. Two parthenogenetic generations follow on peach, then winged individuals migrate to herbaceous plants (secondary hosts), where during the plants' growing season one parthenogenetic generation follows another. In autumn or early winter, winged females are produced on the herbaceous or other plants which migrate to peach or other stone fruit trees. There, the thelytocous females lay female progeny which mate with males and lay the winter eggs. In regions with relatively warm winters, such as Israel, the aphid reproduces parthenogenetically (asexually) all the year round, without the need for winter eggs.

M. persicae is resistant to cold and can develop at temperatures between 5° and 30°C. At 25°C the females live on an average 25 days and lay 60 larvae each (Rivnay 1962). The green peach aphid infests preferably the tips of tender shoots and tender leaves, which are curled as a result of aphid feeding (Figs. 150, 151). In addition to considerable direct injury to the plants, this aphid is a most important vector of viruses causing serious diseases to many species of plants, and especially Solanaceae. Furthermore, the honeydew it excretes, like many other aphids, soils the foliage and fruits, and causes the development of sooty mold fungi (Fig. 152).

Control. Effective natural enemies of aphids must be maintained in the orchard as much as possible (Figs. 23-37), so that no spraying with insecticides is necessary. This can be achieved by using selective insecticides against other pests of fruit trees, but also against this aphid if needed (see Aphididae). When it is necessary to use insecticides against this aphid, it should be done in time, with selective, effective aphicides (aphidocides), whenever a substantial aphid population is observed, and a temperature favoring this insect is foreseen (not very hot weather). On herbaceous plants it is recommended to mix a suitable systemic insecticide with the seed, or mix a granular insecticide formulation with the soil at planting time. This protects the young plants for a few weeks. Systemics in the soil, in granular or other form, may be used also to protect young fruit trees.

Pseudaulacaspis pentagona **(Targioni-Tozzetti)** ***(****Diaspis pentagona)* **(Homoptera, Diaspididae)**, comm. **white mulberry scale, white peach scale, cottony mulberry and peach scale,**

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west indian peach scale, taramas

Adult. The female has an almost circular whitish scale, approximately 2 mm in diameter, with the larval exuvia yellow, off-center and towards the anterior margin of the scale (Fig. 153). Under the scale, the body of the female is oval, short and stout, angular at the sides, so that it looks almost pentagonal. It is yellow or orange, approximately

Figs. 153-155. *Pseudaulacaspis pentagona.* 153.Scales of males and females on bark (photo D. Stamopoulos). 154.Male scales (white) on mulberry shoot. 155.Nectarine branch with scales (light-colored points) of the insect (photo B.I.K.).

1-1.5 mm long. The male adult is winged, pink or orange, with a long and prominent copulatory organ.

Egg. The eggs are under the maternal scale. Those giving male individuals are red-orange, while those giving female ones are white.

Larva. The neonate one (crawler) has an oval body, active legs and antennae, and can displace itself. After selecting a proper site it settles there for the rest of its life. The scales of female larvae have the shape

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of the scale of the adult female, but are yellowish. The scales of the male larvae are oblong, approximately 0.9 mm long, with their sides almost parallel, and are white, except the larval exuvium on their anterior margin which is yellowish (Fig. 154).

Host plants. The species is polyphagous. Dense populations are observed mainly on peach, mulberry and actinidia (kiwi fruit). Among its hosts are other stone fruit trees, pome fruit trees, and broad-leaved forest and ornamental trees and shrubs.

Life history and damage. It completes 3 generations per year at low elevations of central northern Greece, where its seasonal history has been studied (Paloukis and Mentzelos 1971, Paloukis 1979, Kyparissoudas 1992a). It overwinters as a mated adult female, on the bark of trees. Mating of the females destined to overwinter occurs in autumn and oviposition usually the first half of April. A three-year sampling in the Krya Vryssi Giannitsa area of central northern Greece by Kyparissoudas (1992b) showed the presence of crawlers to vary with the year. Those of the first generation were seen from late April to late May or even mid-June, those of the second generation from early to late June until late July or even early August, and those of the third generation from mid- or late August until mid- or late September. Adult males were captured in pheromone traps from mid- or late May to late June or mid-July, from mid- or late July to late August, and from early or mid-September to late October or early November. Trencheva (2002) gives approximately the same periods of occurrence of the various stages of the life cycle for southwestern Bulgaria. Paloukis (1979) gives, for the area of Veria (also central northern Greece), quite later than Kyparissoudas the periods of appearance of crawlers of each generation. As happens with most phytophagous insects, it is natural that the periods of starting, maximum, and ending of every active stage of the life cycle vary, more or less, within a given wider region, depending on the locality, the year, and the species, cultivar and condition of the host tree. The crawlers of the same sex have the tendency to settle one next to the other. This creates on certain branches or parts of branches colonies of male individuals which are white, and in other sites colonies of female individuals. This insect settles mostly on shoots, branches (Fig. 155) and trunk. Only seldom it settles on fruits, and very seldom on leaves. Infested fruits have a lower commercial value, even if the scales are removed, because red spots remain, as happens in peaches (Paloukis 1979). Trencheva (2002) mensions that in southwestern

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Bulgaria, high population densities for consecutive three years may kill a tree.

Control. As is the case with most Diaspididae, the susceptible stages against which should insecticides be applied are the crawler and the settled first-instar larva. If the insect's population is dense, the first spray should be done immediately after the appearance of the first crawlers in spring (approximately late April), and the second spray 12-14 days later (Kyparissoudas 1992). Against the third generation, one spray usually suffices. Against the second generation no specific spray is needed, because in that period the crawlers are killed by the sprays done against other insect pests of peach. If the insect's population is not dense (medium or light infestation), the spray is applied 7-10 days after the appearance of the first crawlers. The sprays against the larvae of the 2nd and 3rd generation can be applied 33 and 27 days respectively after the capture of the first males in pheromone traps (for details see Kyparissoudas 1992). Many organophosphorous insecticides alone, or in combination with a summer oil, summer oils alone, and substances regulating insect growth, such as buprofezin and fenoxycarb, have been used against this scale insect (Paloukis 1979, Kyparissoudas 1992). Sprays should be done carefully, using proper high-pressure sprayers, so that every part of the tree be covered by the spray liquid.

Among the parasitoid and predatory entomophagous insects which are enemies of scale insects generally, a parasitoid wasp, *Encarsia (Prospaltella) berlesei* (Howard), is an effective enemy of *P. pentagona,* and occurs in Greece. The whole spray program against the scale insect in peach orchards of northern Greece should be such as not to eliminate the populations of this wasp. Kyparissoudas (1992) suggests that summer oils or insect growth regulators be preferred, which are milder for this parasitoid. The use of such substances is recommended especially in September, when the parasitoid exhibits its maximum activity. Kyparissoudas also suggests to spray only trees strongly infested by the scale insect, so that on unsprayed slightly infested trees *E. berlesei* and other useful entomophagous insects may survive. Therefore, the most correct control of this scale insect seems to be within the frame of integrated control of peach pests.

Sphaerolecanium prunastri **(Boyer de Fonscolombe** *(Eulecanium prunastri)* **(Homoptera, Coccidae)**

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Adult. Like all scale insects, the female is apterous. Its body is hemispherical, and when at the age of viviparity it is shiny black on the dorsum and 3.5 x 3 x 2.5 mm (Fig. 156). The young immature adult female, which is not full of mature eggs, is yellow on the dorsum, with brown-black spots in 6-8 cross lines, and has average dimensions 2.5 x 1.75 x 1 mm, according to Avidov and Harpaz (1969). The male is winged.

Fig. 156. *Sphaerolecanium prunastri*. Adult females and exuvia of male larvae (white) on twig of an ornamental plum (photo B.I.K.).

Larva. The female has 3 larval instars, whereas the male 2 larval instars followed by the stages of prepupa and pupa. Pupation of the male occurs under a fine whitish waxy cover or case, 1.5 x 1 mm. The neonate larva is elliptical, 0.45 x 0.24 mm, red-brown on the dorsum and light brown in the venter. At the tip of its abdomen there is a pair of fibers as long as half its body.

Host plants. *S. prunastri* is a polyphagous species. It occurs more often on Rosaceae and especially on stone fruit trees (plum, prunella, cherry, peach, almond, ornamental plum, and others).

Life history and damage. It completes one generation per year. It overwinters as a second-instar larva on the bark of branches and twigs. In spring, from March on, the larvae that have overwintered become active, complete their growth and become adult. In the Naoussa area of central northern Greece, the overwintered larvae become active in early spring. According to Argyriou and Paloukis (1976) third-instar larvae (L3) are seen in March-May, adult females in April-June, a few L1 in June, a few L2 in August, and most L2 from September to February. The newly formed adult females are reproductively immature (prozootoky stage). They continue to grow in April-May and become reproductively mature from early June on. At that time adult males also appear. The females are ovoviviparous, or (according to certain authors) viviparous, and lay 1000 or more

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larvae (Silvestri 1939). In Crete L3 are seen mostly in March, adult females in April-May, L1 in May-August and some even as late as October, and L2 from September or October to February. The neonate larvae (crawlers), after searching for a suitable site, settle on twigs and branches of a diameter up to 6 cm, and start sucking sap and developing (Argyriou and Paloukis 1976). Seasonal development in Attica (central Greece) is similar to that in Crete (P. Katsoyannos 1994b).

This scale insect infests shoots, twigs, branches and trunk. In addition to sucking the sap of young shoots, this scale insect excretes abundant honeydew, especially in spring and early summer during its last larval stadia and as adult. This causes the development of sooty mold which injures leaves and fruit. When the population of the insect is dense, twigs, branches and leaves may be killed, the tree weakened and production reduced. In northern Greece it has been especially harmful to peach, while in Crete and Thessaly to almond (Argyriou and Paloukis 1976).

S. prunastri has effective natural enemies which usually limit its population density to unimportant levels from the agricultural point of view. When, however, for various reasons, and usually because of the indiscriminate use of insecticides its natural enemies are eliminated, the scale insect can multiply locally to an extent that requires intervention with chemical means.

Control. Spraying with summer oils or organophosphorous insecticides are carried out when most of the scale's population is in the first and second larval instar, usually in July. A spray in winter may also be effective, with a proper insecticide such as an organophosphorous one and, except peach, a winter oil. Winter oils may injure certain cultivars of peach.

Calocoris **spp. (Hemiptera, Miridae)**

Pegazzano (1958) reported that in peach orchards of the area of Livorno, central Italy, injury to peach fruit was caused by four bugs of the Miridae, namely *Calocoris (Closterotomus) fulvomaculatus* De Geer, *Calocoris (s. srt.) norvegicus norvegicus* Gmelin, *C. (s. str.) norvegicus vittiger* Reut., and *C. (Closterotomus) trivialis* Costa. Especially on the cultivar Hale, the feeding punctures in the mesocarp of young peaches caused necroses which developed to deformed, dark-spotted fruits, with deep scars and abundant gum emission. All these

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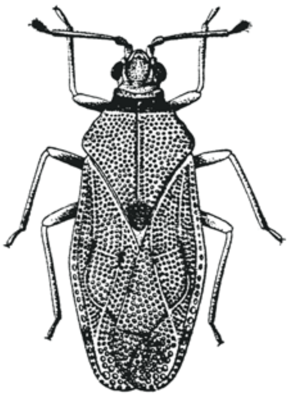
four bugs are polyphagous. They overwinter as eggs in crevices of the bark. First-instar larvae were seen in late March on herbaceous Gramineae and Leguminosae. At approximately mid-April they moved to tender peach foliage and newly-formed young fruits. On the peach trees they developed to L2 and last-instar larvae. The injury was evident when the peaches were 4-5 cm in diameter. From the end of April on, the larvae returned to the herbaceous plants. The adults which were formed in mid-May preferred the floral parts of plants such as olive and grapevine. In the Livorno area in 1957 up to 100% of fruits of young peach trees and 30-40% of older trees were damaged by the bugs. For details see Pegazzano (1958). Regarding *C. trivialis* see also insects of the olive tree.

Monosteira unicostata Mulsant and Rey (Hemiptera, Tingidae)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Adult. The body is oblong, oval, 2.2-2.5 mm long, and light brown. There are 5 tubercles on the head dorsally, and a median keel along the pronotum. The pronotum and the hemielytra (forewings) bear many small cavities (Russo 1959) (Fig. 157).

Host trees. Almond, cherry, pear, poplar, willow and certain other trees.

Fig. 157. *Monosteira unicostata* adult (Silvestri 1939).

Life history and damage. It has been observed on almond in Greece and Cyprus (Mourikis and Basilaina-Alexopoulou 1975, Georghiou 1977), but no considerable injury has been reported there. On the contrary, in southern Italy and Sicily, it causes serious damage to certain almond cultivars. In southern Italy it completes 3 generations per year. It overwinters as adult, under fallen dead leaves and in other refuges on or near the trees. With the beginning of the new tree growth, the adults go to the underside of young

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leaves, which they pierce and suck. Oviposition and development of larvae by piercing and sucking the leaves occurs also on the leaf underside. The life history and way of attacking the almond tree, resembles those of the related species *Stephanitis pyri* which infests pome trees. When the population is dense, it causes complete defoliation of the tree (Russo 1959, Moleas 1987). Against threatening populations a spray with a contact insecticide is recommended.

Thysanoptera (thrips)

In addition to the polyphagous *Frankliniella occidentalis* (treated in the chapter on pests of grapevine), there are other species of the genus *Frankliniella* that attack fruit trees, ornamental and floricultural plants, and vegetables. Marullo and Tremblay (1993) give the most important morphological characteristics for the separation of the five species of this genus that occur in Italy. One of them is *Frankliniella intonsa* Trybom, which is polyphagous and causes deformation of shoots, flowers and fruits, especially of nectarine. On the pistil of nectarines the lesions are suberized and result in deformed fruitlets.

***Capnodis tenebrionis* L. (Coleoptera, Buprestidae)**, comm. **flat-head borer, broadhead worm, capnodis of stonefruits**

Adult. It is generally opaque black (except the pronotum), and 15-30 x 7-12 mm. The pronotum is approximately twice as wide as long, and twice as wide as the head. The pronotum in males is 8-9, and in females 9-10 mm wide. The pronotum is white or light grey and has black spots of various size and shape as well as black dots. The spots correspond to slightly convex sites of the integument. There are two such raised spots on each side of the pronotum, one approximately circular near the anterior, and one larger and oblong reaching the posterior margin of it. The elytra are black and have many concave points along lines. Also they often have disperse whitish spots (Fig. 158).

Balachowsky (1962) states that *C. tenebrionis* is the only species of the genus that is injurious in western Europe and North Africa. The other *Capnodis* are disturbing in eastern Mediterranean, Near East, Middle East, Pakistan and elsewhere. Species of

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Figs. 158-159. *Capnodis tenebrionis.* 158. Adult. 159.Larva (photo B.I.K).

Capnodis have been studied by many authors. Yet, mistakes in species identification occurred in many important studies. In some species there are strong variations in size, color reflection, design and distribution of spots on the pronotum and the elytra. Therefore, careful species identification is necessary in future studies, and reservations are justified when data on seasonal development in a given area differ between authors. Until there is evidence to the contrary, we consider that the species injurious to stone fruit trees in Greece is *C. tenebrionis.*

Egg. Oval, white iridescent, 1.5 x 1.2 mm.

Larva. The young one is 3.5 mm long, white, with dark head and mandibles and a thorax distinctly wider than the abdomen. In the next instars the body is apodous, long and narrow, notoventrally flattened and with the thorax much wider than the following abdominal segments, as is the case with many species of the same family, known as flat-headed borers (Fig. 159). It is white or whitish, except the head which is brown and the prothorax which is light brown or pale. The mesothorax has in the middle a groove in the shape of an inverted V. When fully grown, the larva is 65-100 mm long, or according to some authors 60-70 mm.

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Host trees. The bark- and wood-eating larva infests and develops primarily inside stone fruit trees, secondarily in other trees such as apple, quince, *Mespilus germanica,* and seldom in pistachio and hazelnut. The adult eats the foliage of stone fruit trees, pome trees and perhaps of other trees.

Life history and damage. From observations in Mediterranean countries other than Greece, it is concluded that it completes one generation per year, or one in every two years. The same is mentioned by Isaakides (1936a) and by Anagnostopoulos (1939). Unpublished observations by P. Mourikis and collaborators in coastal Corinthia (Peloponnese) on apricot, give one generation per year. We do not know whether in other areas and conditions of Greece the life cycle in biannual. According to Balachowsky et al. (1962), where the life cycle is annual, the beetle overwinters as adult in various refuges. Pelekassis (1984) mentions that the beetle overwinters as larva of various instars, and as adult. On the other hand, the observations in coastal Corinthia on apricot show it overwinters either as fully grown larva, or as a relatively young larva (mainly second instar). This could be explained by accepting semivoltinism in part of the population that may exhibit diapause the first winter as L2, then the second winter as fully grown larva. When the insect overwinters as grown larva, it pupates and becomes adult in spring. The first ovipositions of May will give larvae which will manage to reach full growth until the end of autumn. Larvae from summer ovipositions reach the autumn mainly as L2 and some as L3, overwinter, become active in spring, and complete their growth and pupate in late spring and summer. The adults emerge from the pupal chambers, feed and oviposit during the whole warm season. In areas where the insect is semivoltine, the larval stage lasts over a year, and the first winter must be passed in the larval stage. Referring to non-irrigated pistachio trees in central Greece, Mourikis et al. (1998), state that it is generally univoltine, but that if oviposition is delayed until September, semivoltinism may occur. In that non-irrigated pistachio orchard, it overwinters as larva. The larvae pupate in March and April, and the adults emerge in May-June. The female oviposits on the soil “15 cm from the trunk”. Twelve to 18 days later, the larvae hatch and move towards the trunk, where they bore a gallery in the bark and then proceed to the roots. In localities or areas where the beetle overwinters as adult, it becomes active in spring, feeds for weeks on the foliage of host trees, and matures reproductively from May to mid-summer. It is long-lived

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and oviposits mainly during summer. In Palestine the adult beetles were observed to feed on the bark of soft twigs and not on leaf blades (Rivnay 1947). They tear off the soft bark and chew rather than cut it. Twig buds are their favorite food. The stalks of the leaves around buds are also readily eaten and the leaves drop to the ground. Fresh leaves on the ground may disclose the presence of the pest on the tree.

The female lays its eggs one by one or in small groups mainly on the soil near the base of the trunk, and less often in fissures of the bark of the base of the trunk, near the soil. The young larva enters the crown or the base of a root and bores a gallery in the inner layers of the bark and the cambium up to the wood, but also in the wood (Anagnostopoulos 1939, Balachowsky 1962). According to Isaakides (1936a), the larval gallery is first bored in the bark, and subsequently deep in the wood, whereas according to Anagnostopoulos (1939) it goes along the inner bark and outer wood. The galleries are usually at the crown level, but proceed upwards and downwards until the basal roots. The larval gallery is reported to reach a length of 50 cm, and by some other authors 150 cm. Pupation takes place in a chamber that the grown larva makes in the outer wood and bark near the tree crown.

C. tenebrionis is considered a serious enemy of stone fruit trees. The injury caused by the larval galleries to the bark and wood of the trunk and the central roots, especially of weak or abandoned trees, could be serious, leading sometimes to the death of the trees. Anagnostopoulos (1939) mentions that when the trunk is not of great diameter, the larval gallery may encircle it completely and thus kill the tree. The feeding of adults on the foliage in spring and summer prior to reproductive maturity is not considered serious. Because infestations of pistachio trees are rare, it is not considered a serious pest of that tree.

Fig. 160. *Ptosima flavoguttata* adult on prunella foliage (photo B.I.K.).

Control. Against *C. tenebrionis* and other wood borers of the same genus which live and attack trees in a similar way, cultural and chemical measures are recommended. These measures do not protect the trees completely, but at least limit the

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injury if they are applied carefully and systematically. These measures are the following: 1) Planting of healthy young trees housing no larvae of this borer. 2) Regular irrigation and fertilization, both in the nurseries and the orchards, so that the trees be maintained vigorous. 3) In small orchards, collection of the adult beetles by hand. 4) When considered necessary, killing of the adults by insecticides. Spraying of the trees, and especially of the trunks, in summer, with proper insecticides. In southern Italy, spraying of branches of plum trees with a proper organophosphorous or carbamate insecticide in summer, when the adults were active on the foliage, killed a high percentage of them, even when some were caged on sprayed branches 2 weeks after the spray (Colasurdo et al. 1997). Against young larvae, before they penetrate the tree, watering around the trees at a radius of 50-60 cm, in summer and early autumn, with 12 g/m^2 lindane or endosulfan in 10-12 liters of water was applied. The watering was repeated every 40-60 days.

Other related species with a similar appearance and habits which have been recorded on stone fruit trees in Greece or in Cyprus, but which are less frequent and less harmful than *C. tenebrionis,* are: *C. carbonaria* Klug, 23-32 mm long, *C. porosa* Klug, *C. tenebricosa* Olivier, 16-19 mm long, and *Aurigena unicolor* Olivier. For details see Balachowsky et al. 1962 and for *C. carbonaria* Avidov and Harpaz (1969). The species *Ptosima flavoguttata* (Fig. 160) was found on abandoned plum trees in the Thessaloniki area by the junior author.

Teratolytta dives Brullé (Coleoptera, Meloidae)

Adult. It resembles in shape, size and color *Lytta vesicatoria* (see insects of olive). It differs in having along the outer side of each elytron a shiny dark red stripe.

Life history and damage. It has one generation per year. The adults cause damage by feeding on the foliage of various trees and other plants, in spring. It was observed in Florina (northwestern Greece) feeding on apple leaves (Isaakides 1936a), and in Kopais (central Greece) on the foliage of broad beans, *Vicia faba* (Ayoutantis et al. 1952). On the Aristotelian University Farm, in early April 1980, the senior author noticed a few dozens of adults, most of them in coition, on or near eroded almond leaves, and a few days later a substantial number on or near pear flowers with their petals eroded. Adults and

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injury to the foliage of almond was recorded in the same orchard also in early April 1978. This beetle is controlled with the same measures as its relative *Lytta vesicatoria.*

Figs. 161-162. 161.*Rhynchites auratus* adult. 162.*Involvulus cupreus* adult (Calwer 1893).

Rhynchites auratus **Scopoli (Coleoptera, Attelabidae)**, comm. **cherry weevil**

Adult. It resembles *Rhynchites bacchus* (see insects of pome fruit trees), but it is bigger (Fig. 161). It is 5.5-10 mm long, and has a metallic copper color, very bright, with purple reflections on the rostrum. The male has on each side of the prothorax a spine, as have certain other species of weevils (e.g. *R. aereipennis).*

Host trees. Mainly cherry and sour cherry, and less often apricot and plum.

Life history and damage. In former Yougoslavia, where it was studied by Lazarevic[2] (the data taken from Balachowsky and Hoffmann 1963), most of the population completes one generation every two years, and a smaller proportion one every year. In the first case (of semivoltinism), it overwinters as grown larva the first winter in a cell in the soil, and the second year as a reproductively immature adult, also in the soil, inside the pupal cell. In the second case (of univoltinism), it overwinters as immature adult in the pupal cell. In spring, the adults, after feeding on buds, flowers and young fruits for a few weeks (Fig. 71), oviposit deep in the mesocarp, near the endocarp. The young larva penetrates the endocarp and eats the seed. When fully grown it drops to the soil, where it remains in a cell it constructs, until the end of summer, or more often until the next (second) summer. It becomes adult in autumn and the adults emerge from the soil the next spring. *R. auratus* is considered as the most harmful weevil to the stone fruits of Europe. The feeding holes, with the margins often suberized, make the fruits unsuitable for consumption, as is also caused by the oviposition holes and exit holes

[2] Initials not given.

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of grown larvae.

Control. A spray with a suitable contact insecticide is recommended in spring, as soon as erosions of fruits are detected, or adult weevils are seen on the trees in dangerous numbers.

Among the species of weevils that infest stone fruit trees in southern Europe and the Middle East are: *R. aequatus* on various stone fruit and pome fruit trees, *R. smyrnensis* on stone fruit trees and apple, *R. zaitzevi* on almond, and *Involvulus cupreus* (Fig. 162) mainly on plum and apple.

Anthonomus amygdali **Hustache** *(A. ornatus)* **(Coleoptera, Curculionidae)**, comm. **anthonomus of almond**

Adult. It is 3-4 mm long, rostrum included. The basic body color is dark brown. The head is almost black and the rostrum brown or rusty. The pronotum and the legs are reddish. Along the pronotum there is a whitish stripe. The elytra in their anterior corner are reddish in the male and red in the female, and have three cross stripes which are grey in the male and yellow in the female (Hoffmann 1963a). According to a description by Anagnostopoulos (1939), the elytra are whitish, with two dark cross stripes, one of them at approximately the middle, and the other near their posterior margin.

Host trees. Principally almond, and secondarily peach and apricot.

Life history and damage. It has one generation per year, and is active in winter and spring. The adults pass the summer inactive at various protected sites on or near the trees, such as fissures of the bark, under dry bark, under herbaceous plants, in the soil, or elsewhere. They become active from early November on (Isaakides 1936a). After feeding for approximately two weeks on buds, they mate and begin ovipositing from December to late February, depending on the area. With its rostrum the female opens an oviposition hole and inserts an egg in every flower bud. If the bud has not yet developed, the larva eats the petals, the stamens and the pistil. If the bud has started to develop, the larva eats the stamens, the pistil and the interior of the calyx. It pupates inside the eroded bud or the closed flower, which by that time may have fallen to the ground. Anagnostopoulos (1939) mentions that, in the Athens area, the larvae complete their growth the second decade of March, and the adults appear in the first half of April. Approximately the same seasonal history of this insect is

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reported for southern Italy (Sarra 1929).

The infested flower buds dry without opening and ultimately fall to the ground. Falling off the tree is helped by the shaking of the larval body in them. The larva makes the fallen buds "jump" when we move them slightly. In Greece, serious damage by this weevil has been observed only locally and not frequently. Erosions of buds and tender leaves in spring by the adults are usually of no economic importance.

Control. In almond orchards where a high percentage of flower buds is destroyed, a spray is recommended with an organic synthetic insecticide in April-May, when the adults are seen on the foliage. In orchards where a spray is carried out that season against the almond seed wasp, *Eurytoma amygdali,* suffices against the weevil. If there is indication that the adult weevil population on the trees in autumn is dense, a spray with a contact insecticide is recommended in November.

In countries neighboring Greece, there are some more species of *Anthonomus* infesting the flower buds of almond in a way similar to that by *A. amygdali.* In some cases they cause serious damage. They are: *A. cyprius, A. gemmicola, A. gentilis, and A. ornatoides* (Lodos 1955).

***Scolytus rugulosus* Mueller *(Ruguloscolytus rugulosus)* (Coleoptera, Scolytidae), shot-hole borer**

Adult. It is 1.8-2.7 mm long. The body is dark chocolate brown and dull. The pronotum and elytra are black, the latter having a reddish tip. The prothorax has

Fig. 163. *Scolytus rugulosus* adult on side and dorsal view (photo N.T. Papadopoulos).

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dense rough, long and narrow dots. The frons has no keel (Fig. 163).

Host trees. Cultivated and wild Rosaceae, with preference to almond, apricot, peach, cherry and apple.

Life history and damage. According to Isaakides (1936a) it completes 2 generations per year. Observations by Markalas et al. (1994) in the Aghia Larissa area of central Greece, led them to the conclusion that 2 generations per year were also completed in cut-off pieces of almond trunks. The adults of the first generation of the year were observed from mid-September to late October, and of the second generation from mid-April to early June of the following year. It overwinters as a fully grown larva in its gallery. It pupates and becomes adult in spring, at the end of the larval gallery. In spring the adults emerge and feed on buds or young shoots to which they may cause light injury. Subsequently the female bores a maternal gallery in the inner bark, extending a little to the surface layer of the sapwood, and oviposits along its sides. The maternal gallery is parallel to the branch axis and relatively long, up to 40 mm. *S. rugulosus* bores maternal galleries in branches of a diameter of 4-6 cm or twigs of 1-2 mm, or in the upper part of the trunk of young trees. It is reported that the female lays on the average 50 eggs. The larval (offspring) galleries are at first vertical to the maternal one, and later deviate. They also are relatively long. A group of such galleries of a species related to *S. rugulosus* is seen in Fig. 102.

Fig. 164. Gum on a main branch of a peach tree that came out of entrances of maternal galleries and of exit holes of adults of a species of Scolytidae (photo B.I.K.).

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This bark beetle usually infests weak trees, but can infest also vigorous trees, especially during the dry season (summer to autumn). On *Prunus* trees, gum is observed at the sites of maternal galleries (Fig. 164). In vigorous trees it is believed that the gum can kill the larvae. This bark beetle is very harmful, because it may kill branches and even whole trees when it destroys perimetrically a large part of the cambial zone of the trunk. In Aghia Larissa, almond trees heavily infested by the beetle, which were killed in spring, were found with their roots infected by the fungus *Armillaria mellea.* According to Markalas et al. (1994), the fungus was, probably, the primary cause of weakening of the trees.

Control. Same as against the other bark beetles that infest fruit trees, cultural and mechanical measures are mainly taken. Any measure is recommended that maintains the trees in good vegetative condition, such as proper fertilization, irrigation, and pruning to remove in time twigs and branches that are weak, half-dead, or infested by the beetle. The twigs and branches that are pruned off should be destroyed with fire or other means, before the insects inside them become adults. If possible, it is recommended to keep the cut-off twigs and branches for some time inside a cage of fine-mesh wire screen, or in a nearby warehouse with such screen in the windows. This will allow beneficial parasitic insects that keep the bark beetle's populations low, to come out and continue their beneficial activity. The use of trap twigs is also a recommended measure. A little before the period of oviposition of the beetle, we hang in the trees bunches of twigs, or form on the soil small piles of half-dead twigs or pieces of branches. The females oviposit preferably there, and oviposition in the trees is limited. The trap twigs should then be destroyed in time. Control with insecticides is recommended only in certain cases. We then use contact insecticides of long residual action, to kill the adult beetles before they enter the tree. More than one insecticidal applications are necessary to protect the trees during the two periods adults occur in the orchard. These periods must be determined for each area and species of tree.

Other related species with a similar life history that also infest Rosaceae, are *Scolytus mediterraneus* and *S. amygdali.* The first one is more rare in southern Europe, but abounds in North Africa, the Middle East and Crimea. It causes serious damage to cherry, apricot and almond, while it can infest also apple and certain other Rosaceae. The second species infests mainly almond, and more rarely other stone fruit trees, pome trees, or other Rosaceae. They are controlled

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with the measures given above for *S. rugulosus.*

Contarinia pruniflorum **Coutin and Rambier (Diptera, Cecidomyiidae)**, comm. **apricot flower midge**

This midge was first recorded in Greece in 2006, in certain apricot orchards of northern Peloponnese. The percentage of infested flowers reached 60-65%, and late apricot cultivars seemed to suffer the greatest damage (Tsagkarakis and Mitsopoulos 2007). This univoltine midge has long been known as a pest of apricot in other Mediterranean countries such as France, Spain and Italy. The midge oviposits between the petals of the closed flower buds, and the larvae, 3 or more per bud, feed on and destroy the receptacle and stamens. Fully grown larvae drop to the soil where they pupate. The adults emerge in spring. Flower buds housing a few larvae may allow the setting of fruit, which however remains small and in most cases drops (Tsagkarakis and Mitsopoulos 2007).

Rhagoletis cerasi **(L.) (Diptera, Tephritidae)**, comm. **cherry fruit fly, European cherry maggot, cherry worm**

Adult. It is 4-5 mm long, with a shiny black body, the anterior part of the head and the antennae yellow or yellowish, and the scutellum strongly yellow. The femora are black and the tibiae yellow. The wings are iridescent and have four black stripes in a characteristic pattern. Three of them are cross stripes, while the fourth one extends along the apical part of the anterior margin of the wing, covering also the apex. The third cross stripe and the fourth one unite at an approximately right angle. On the anterior margin of the wing, between the 2nd and 3rd cross stripes, there is usually a small black oblong spot (Figs. 165-166). The males are smaller than the females.

Egg. White, long and narrow, ellipsoid, and slightly curved.

Larva. It is acephalous and apodous, same as the larvae of all Tephritidae, with the cephalic end of the body narrower than the anal end (Fig. 167). The young larva is 0.6 mm, and the fully grown one 6 mm long. The color is white or yellow-white.

Pupa. The pupal cover (puparium) is ellipsoid, 4 x 2 mm, straw-yellow or dull light brown, with the intersegmental lines distinct (Fig. 168).

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Host trees. Fruits of cherry (*Prunus avium* L.) and less often of sour cherry *(P. cerasus* L.). The fly also infests fruits of species of *Lonicera* (Caprifoliaceae), and especially of *L. xylosteum* L. and *L. tartarica* L., which are rare in Greece. The female oviposits in semiripe fruits and the larva grows and develops in fruits which approach maturity or are ripe.

Life history and damage. It completes one generation per year. However, a small percentage of the population may continue its dormancy for over a year, thus completing its generation in two years. Much of this dormancy is diapause. It overwinters as pupa in the soil. The adults emerge from the soil in spring, usually in May, when the cherries are susceptible to infestation i.e. to oviposition by the fly, or a little earlier. At that time the cherries change color from yellow towards pink. After feeding for a few days, maturing sexually and mating, the females oviposit in cherries and other host fruits which start to mature. Using its ovipositor, the female opens a hole in the fruit and inserts an egg in the mesocarp (flesh of fruit) (Fig. 166A), approximately as the olive fruit fly does in olives. Right after oviposition, the female, with its ovipositor deposits on the fruit surface an oviposition-deterring pheromone. This pheromone deters new ovipositions in already oviposited fruits (B. Katsoyannos 1975). In nature the female is considered to lay 100-200 eggs on the average. The larva bores a gallery in the mesocarp which constitutes its food (Fig. 167). When it completes its growth, it abandons the fruit and drops to the soil, where at a small depth of 2-10 cm it pupates and remains in dormancy, the largest part of which is diapause, until the next spring. For details on the seasonal development of this fruit fly, especially in northern Greece, as well as on its trapping and control, see B. Katsoyannos (1996b). As expected, the season of appearance of the adult population may differ between areas differing in climate, as well as between years. The beginning, maximum and end of captures of aduls in Rebell type yellow sticky traps (Fig. 169) was, respectively, 7 May, 22 May, and 6 July 1996 in Micra Thessaloniki, 14 May, 24 May and 28 June in Kolindros Pieria, and 25 May, 30 June and 28 July in the more hilly Dafni Kozani (Stavridis et al. 1997, B. Katsoyannos et al. 2000). Monitoring the fly population and fruit infestation for a second year in seven localities of northern Greece by Aristotelian University scientists lead to the following conclusions (B. Katsoyannos et al. 2000): The percentage of fruits infested by the fly differed between cherry cultivars and localities. In late-maturing

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cultivars there was a positive correlation between fly population density (captures in traps) and percentage of infested fruits. On the contrary, in early or half-early cultivars (with one exception) the percentage of infested fruit was not related to fly population density. In those cultivars, despite a density of 150-200 flies per trap during the whole presence of flies in the orchard, fruit infestation was below the limit of tolerable density of 2-4%. It was concluded that to set intervention thresholds in each locality and cultivar, measurements of fly population density and fruit infestation should be repeated over several years. This should be the task of local interested parties.

Damage by this fly can be serious. In years of dense populations of the fly, the percentage of infested cherries or sour cherries exceeds 50% and may reach 100%. The presence of the larva, whether young or grown, is not detectable easily, unless we open the fruit. Damage is more serious in table cherries, while in those destined to distillation even a medium infestation is tolerable. Many countries have set as a limit of tolerable infestation 2-4% of cherries, whether they are destined for the fresh market or for canning. As the distinction of infested from healthy cherries is not practically possible at harvest, the damage to the grower may be very heavy if the cherries reaching the buyer are then found suitable only for distillation. In addition, the oviposition hole and the larval galleries in the mesocarp favor the entrance and establishment of pathogenic microoorganisms which worsen the condition of infested cherries. Growth of the larva and of microorganisms continues after harvest, up to the consumer of the cherries. The degree of infestation varies with the year, the cultivar and earliness of the cherries, as well as the location and exposure of the orchard. The type and humidity of the soil affect the mortality of pupae. The presence of reproductively mature adults when the fruits are suitable for oviposition, contribute to high percentages of fruit infestation. Therefore, certain cultivars are more resistant than others, because of earliness or lateness of fruit maturation.

Control. Many organophosphorous and other synthetic insecticides are effective against the adult flies. However, great caution must be taken so that the application is timely and the insecticide proper, so that no unacceptable quantities of insecticide residues remain on the fruits at harvest. This is important because a few, only 2-3 weeks, intervene between the beginning of fruit infestation and fruit harvest of most cherry cultivars.

In continental Greece, control by cherry growers consists mainly

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Figs. 165-169. *Rhagoletis cerasi.* 165. Adult. 166. Adult on a cherry fruit. 166A.Female ovipositing (photo B.I.K.). 167. Larva inside a sweet cherry fruit (photo U. Remund). 168.Pupae. 169. Yellow color trap used for the capture of the adult flies (photo B.I.K.).


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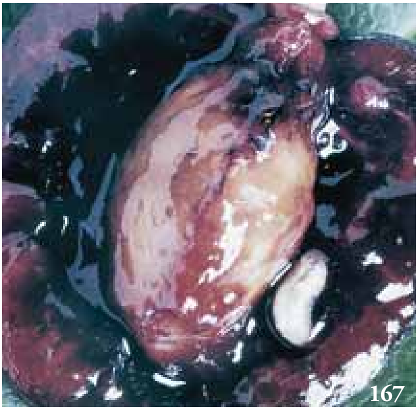
166A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of two cover sprays against adults and larvae in the fruit. These sprays are done usually "by the calendar", i.e. irrespective of the presence of a fly population. On Crete, 2 bait sprays were usually applied. The spray liquid contained 0.3% fenthion and 4% protein hydrolyzate (Entomozyl or Dacus bait). The first spray was done as soon as flies appeared, and the second 10 days later, with 0.1-0.3 liters of spray liquid per tree. The adult fly population is followed there with yellow sticky traps bearing also a little sac with ammonium bicarbonate (Haniotakis et al. 1991). In the hilly location of Daphni Kozani, in northwestern Greece, 2 bait sprays in June, 10 days apart, resulted in 15 times fewer flies caught in the traps, and in only 7.6% infested fruits versus 77.8% in the unsprayed control (B. Katsoyannos et al. 2000, Papadopoulos and B. Katsoyannos 2003).

In northern Greece, chromatic (color) yellow traps of the Rebell type (Fig. 169) were effective for the following-up of the fly population and perhaps also for its control with mass trapping. Six year's experiments in the Micra Thessaloniki area showed that despite the traps capturing a relatively high number of adult flies, infestation of early cherries and sour cherries was as a rule so small that no insecticidal applications were justified (B. Katsoyannos 1996b and references therein). Many years records with color traps in the main cherry-producing areas are necessary to determine intervention population thresholds by cultivar and location, in conjunction with the development also of other methods of control (except insecticides), such as mass trapping, or the use of an oviposition-deterring pheromone. Anyhow, no insecticide sprays should be done when the traps do not catch flies.

In Italy, as also in Switzerland, when the flies captured in the traps surpass the intervention threshold which, depending on the area and the size of the expected crop is 0.1, or 2 insects per trap, a spray is carried out with 0.05% dimethoate or 0.1% formothion, not later than 15-20 days before harvest. This spray kills both adults and larvae in the fruits, without leaving unacceptable residues in the cherries. Other useful measures are timely harvesting, planting early-fruiting cultivars, and the careful picking of all fruits at harvest, so that no infested fruits remain in the orchard to produce a substantial overwintering population of the insect.

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Phyllonorycter cerasicolella (Herrich-schaeffer)

In northern Italy and Hungary this species infests stone fruit trees, among them peach, cherry, apricot and plum, but may also be found on apple (Zangheri et al. 1992). The adults and larvae resemble very much those of *P. blancardella.* In northern Italy it is considered to complete 4 generations per year. It overwinters as fully grown larva inside its gallery in the fallen leaves. Pupation occurs in late March to early April, and the adults start appearing in mid-April. There is overlapping of generations. The larval gallery in the leaf is first long and narrow, but later widens. For details see Zangheri et al. (1992).

Anarsia lineatella Zeller (Lepidoptera, Gelechiidae), comm. peach stem borer, peach twig borer, chocolate worm, anarsia

Adult. It has a length of 7-8 mm, and a wing span of 14-18 mm. The body is dark grey, the forewings dark brown, sometimes almost black, with light brown spots. The hindwings are of lighter color, grey-brown or red-brown, and have a pointed apex. The maxillary pulps are big and erected upwards. When at rest the adult keeps its wings at an angle like a roof above its body, but not completely closed (Fig. 170). According to Zangheri et al. (1992), the moths which as larvae fed and grew in shoots are smaller than those that grew in fruits of peach.

Larva. It is chocolate brown or red-brown (Fig. 172), with lighter intersegmental zones, i.e. the marginal fore and hind zones of each body segment are lighter than the intermediate darker zone. Thus, the segments are clearly distinguishable. According to Zahgheri et al. (1992) fully grown it reaches 15-16 mm. It has black or dark brown head, prothoracic shield, anal shield and prothoracic legs. The anal prolegs have each, on a line, two groups of 6-7 hooks. Also, there is an anal comb with 4-6 branches or spines.

Host trees. Primarily peach, apricot and almond, and secondarily other stone fruit trees (plum, cherry), apple and pear. This species' distribution is wide, covering regions of Europe, Asia, North America and Australia (Zangheri et al. 1992).

Life history and damage. In central northern Greece 3 generations per year were reported by Mentzelos et al. (1977), and 3 or usually 4 by Damos and Savopoulou-Soultani (2007), depending on prevailing temperatures. In southern Italy and southern France 2 generations

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are reported by Balachowsky and Real (1966). Yet, 3 generations are reported for Italy by Zangheri et al. (1992). In Israel 3-4 generations are completed on peach but only 2-3 on apricot trees (Berlinger 1966, 1969). According to Balachowsky and Mesnil (1935), it overwinters as young first-instar larva, according to Zangheri et al. (1992) as a second-instar, and according to Damos and Savopoulou (2008) as a second or third-instar larva, in a small gallery or chamber it bores in the bark, at the axil of a 2-3-year-old twig. The overwintering site is characterized by a protruding little tube that the larva forms at the exit of the gallery. This little tube, known as "chimney", is straight or curved and approximately 0.5 mm long. It is usually brick-colored, and consists of wood frass, larval excrement, and silk threads. In Greece, overwintering in small galleries, at the axils of twigs 1-5 cm in diameter, is reported by Anagnostopoulos (1939), or at the base of leaf buds at the apical third of shoots of the year (Mentzelos et al. 1977), without mention of the existence of a protruding little tube. In Israel overwintering occurs mainly in apical buds of one-year-old twigs (Berlinger 1966, 1969). Metcalf et al. (1951) mention for north America that the larva overwiners as partly grown, hidden in a silken cocoon closely attached to the bark of trunk and branches.

In spring, when development of leaf buds begins, the larva abandons the overwintering gallery and enters a young shoot at some point near its tip. Subsequently it bores a gallery along the center of the tender shoot, approximately as the larva of *Grapholitha molesta* does (see below). Balachowsky and Mesnil (1935) mention that infestation of young shoots begins early, as soon as they begin to develop, in contrast to *Grapholitha molesta* whose larvae attack shoots after they have reached a length of 15-20 cm. Until it completes its growth, the larva of the generation that overwintered may infest more than one shoots. The apical part of the shoots withers and dies (Fig. 171). According to most authors, the adults of this generation are observed in May-June and oviposit usually on shoots or fruits, and preferably on the pedicel. In peach orchards of Imathia (central northern Greece), the adults of the generation that overwinters first appeared 35-45 days after petal fall of the peach cultivars Elberta and Red Haven (Mentzelos et al. 1977). In addition to shoots, Anagnostopoulos (1939) also observed in Attica larvae injuring fruits of almond, peach and apricot in May. The larvae of the next (first) generation infest the apical part of shoots of the year, and green fruits. The fruits are eroded superficially, near the pedicel, or where a fruit is in touch with a leaf, with another fruit,

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Figs. 170-172. *Anarsia lineatella.* 170.Adult (photo N.T. Papadopoulos). 171.Killing of apical part of a peach shoot by the larval gallery. 172. Erosion of an immature almond by the dark brown larva (photo B.I.K.).

or with a twig. Also, the larvae enter deep in fruits and eat the inner layer of the mesocarp near the endocarp (Fig. 172). When the fruit approaches ripeness or is ripe, infestation (by larvae of the next generation or generations) involves as a rule the interior of the fruit. Almost ripe fruits, depending on the species of tree and the cultivar, are infested by larvae of the first or the second generation. According to Anagnostopoulos (1939), in the Athens area the larvae of the first generation hatch in late May to early June, while those of the second generation appear later, in summer, and injure mainly fruits. Pupation takes place usually in protected sites of the bark of the tree, or in other nearby refuges. The life and symptoms of injury to the peach tree by this moth much resemble those of and caused by *Grapholitha molesta* (below), with which it may co-exist in the same orchard.

A. lineatella is generally considered one of the major pests of stone fruits not only in Greece but also in many other countries (Damos and Savopoulou-Soultani 2010b and references therein). Damage in

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spring to shoots may be important only in very young trees, when apices of tender shoots destined to become main branches of developed trees are killed. However, the damage to fruits by the larvae of this moth may be serious. The relationship between the moth's population density and damage to the yield of peaches, economic injury levels and economic thresholds (intervention thresholds) have been determined after a three-year study by Damos and Savopoulou-Soultani (2010b) in 4 orchards of central northern Greece. The study involved the cultivar "Loadel" destined for industrial processing. Significant relationships were found between yield loss and captures of male moths during their first flight on one hand, and numbers of infested peach shoots (shoot flagging) on the other. The economic injury level was calculated at 112.9 or 123.5 larvae on fruits of sampling branch per 0.1 ha, according to the linear or non-linear model, respectively. The fixed economic thesholds were likewise estimated at 84.7 or 92.6 larvae according to the linear or the non-linear model respectively.

A number of parasitoid hymenoptera have been recorded in Italy as enemies of this moth, but their role in limiting the moth's populations has been moderate (Isaakidis 1936a, Zangheri et al. 1992).

Control. Against larvae that overwinter, a winter spray is considered effective. It is done the period of winter rest of the trees, with an organophosphorous insecticide, and even better with the addition of a summer oil (Anonymous 1973). During the vegetative period of the trees (growing season) on the basis of trap captures of male moths in pheromone traps and on local experience, the Plant Protection Warning Services advise the fruit growers when to spray their trees. Four to five sprays are usually applied, every 2-3 weeks, mainly with organophosphorous insecticides or with substances preventing insect growth. The sprays aim at also controlling *Grapholitha molesta* (see below).

In addition to *A. lineatella,* two more lepidopterous species are among the major insect pests of peach in northern Greece: the oriental fruit moth *Grapholitha molesta* (see below), and the summer fruit tortrix *Adoxophyes orana* (see insects of pome fruit trees). With the purpose of developing simple phenological models that would reliably predict male moth emergence and population dynamics of all these three species during the growing season, Damos and Savopoulou-Soultani (2010a) made a 4-year study in two different localities of central northern Greece using pheromone traps. In the orchards of one locality one peach cultivar was grown, and in the other locality

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two other cultivars. In most cases 3 non-overlapping moth flights were observed. According to their unified model, the first moth flights start with *Anarsia,* whereas the second ones start first with *Grapholitha* and notably later with *Adoxophyes.* Their moth flight calculations and recommendations it is hoped will find field application to IPM systems in peach orchards of northern Greece, and their models verified in more peach-growing localities of the country.

Grapholitha funebrana **Treitschke** *(Cydia funebrana, Laspeyresia funebrana)* **(Lepidoptera, Tortricidae)**, comm. **plum fruit moth, plum carpocapsa, plum worm**

Adult. It has a wing span of 10-14 mm and a dark general color, which somewhat resembles that of *Grapholitha molesta.* Dorsally, the forewings have a dark brown, almost uniform color, and a crescent-shaped white spot in their basal third, near the posterior margin. The large apical spot of the forewings, which extends in their whole width, is dark and not easily discernible, with 4 light-colored parallel lines (Fig. 173). The hindwings are also uniformly dark brown, but lighter than the forewings. The wing margin has a mild fringe (Balachowsky and Mesnil 1935).

Larva. Fully grown it is 11-15 mm long. Dorsally it is reddish. The head and the prothoracic and anal shields are dark brown (Fig. 174). The prolegs have each 35-40 hooks. On the tenth abdominal segment there is an anal comb with 5-6 teeth. (Zangheri et al. 1992).

Host trees. Stone fruit trees, and especially plum trees (*Prunus domestica* and *P. insititia*). Occasionaly it can be found in peaches, apricots and cherries.

Life history and damage. Although it has caused serious damage in Greece, information on its life history in this country is based mainly on only a fairly recent work by Papathanassiou and Athanassiou (2005). These researchers followed the density of the male adult moth population for 4 years in the Lehonia Thessaly area of eastern central Greece, using sex pheromone traps. They caught moths from late March or early April through October. There were 3 peaks, the first in mid-April, the second in the second half of May, and the third in late July to mid-August. They conclude that in that area the moth completes 3 generations per year, and possibly a partial 4th in September at low elevations when temperatures permit. Monitoring

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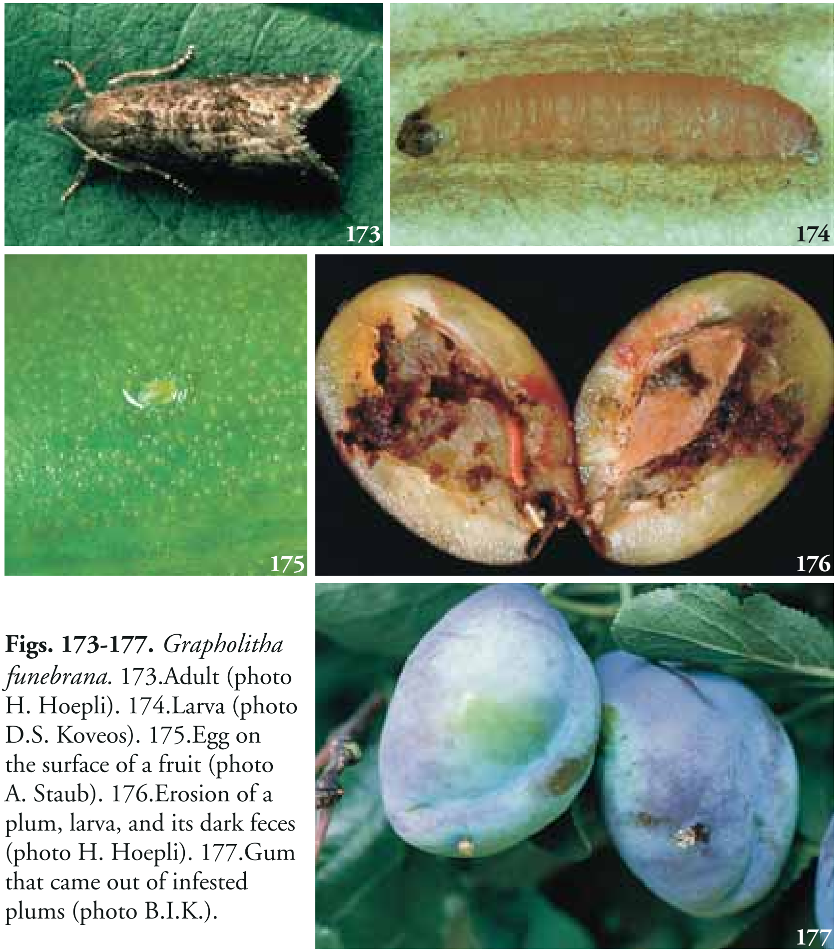

Figs. 173-177. *Grapholitha funebrana.* 173.Adult (photo H. Hoepli). 174.Larva (photo D.S. Koveos). 175.Egg on the surface of a fruit (photo A. Staub). 176.Erosion of a plum, larva, and its dark feces (photo H. Hoepli). 177.Gum that came out of infested plums (photo B.I.K.).

the male moth population with pheromone traps started in 2013 also in a new 18-hectare orchard in northeastern Greece (Ampelidis et al. 2013). In southern Bulgaria 2 generations and a partial third have been observed. In Hungary they used to believe that this moth has 2 generations per year, but it has been established that it completes three. A considerable percentage of fully grown larvae of the 2nd and the total of the 3rd generation enters diapause and develops the following year (Sáringer and Deseö 1972). It overwinters as fully grown larva in a cocoon in protected sites of the bark of trees (mostly

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of the trunk), or in the soil. The adults appear in late spring to early or mid-summer, and oviposit in June or July, when fruit maturation approaches. The female sticks an egg on the fruit pedicel or on the epicarp (Fig. 175). The young larva enters the fruit where it develops feeding on the mesocarp and especially its inner layer, near the endocarp (Fig. 176). When fully grown, it comes out of the fruit from a hole it opens, usually on the side of the fruit, and goes to a protected site on the tree or the soil to spin the cocoon in which it pupates to soon become adult, or remain in dormancy until the next spring, depending on the generation. Gum often comes out of the larva's exit hole (Fig. 177). In West Switzerland, the insect completes 2 generations per year, and only rarely a 3rd flight is observed (Charmillot et al. 1979). In that region although a high percentage of the larvae of the first generation develops uninterruptedly and gives individuals of the 2nd generation, a smaller but still considerable percentage of them enters diapause and develops to the next stage only in the following spring.

Infested fruits are unsuitable for the market. It is reported that the presence of the larva can also cause early fruit drop. The damage to plum production can be serious.

Control. A proper organic insecticide is applied before the young larvae penetrate the fruits. In West Switzerland, where this insect's life history has been studied carefully, the evolution of adult population density and of oviposition (presence of fresh eggs on the fruits) are followed. The appearance of adults is ascertained with pheromone traps, or foreseen on the basis of day-degree summation above the temperature threshold for development (Charmillot et al. 1979). Because damage by the first generation of the insect is not serious there, a spray with a hormone insecticide with ovicidal action is recommended against the eggs of the second generation. This spray is done a little before the beginning of oviposition. If other insecticides without ovicidal action are used, the spray is done a few days later. The insecticide should have such residual action as not to leave undesirable residues on the fruits at harvest.

Grapholitha molesta **(Busck)** *(Cydia molesta, Laspeyresia molesta)* **(Lepidoptera, Tortricidae)**, comm. **oriental fruit moth, oriental peach moth**

Adult. It has a wing span of 10-12 mm, and a general color brown-grey (Fig. 178). The forewings are also brown-grey. The whole aspect

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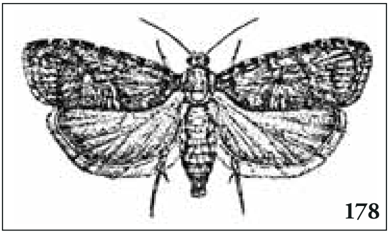
resembles that of other species of the same family, and especially *G. funebrana* (Zangheri et al. 1992).

Egg. Whitish, convex, 1 x 0.9 mm. Depending on the season, it is deposited on bark, leaf, or fruit.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Figs. 178-179. *Grapholitha molesta.* 178.Adult (Silvestri 1943). 179.Grown larva inside a peach (A.U.T.).

Larva. In early instars it is whitish or yellowish. In the last instar it is slightly pink, with light-brown head and prothoracic shield (Fig. 179). Fully grown it is 10-14 mm long. In each of the last two (anal) prolegs there are 25-30 hooks, and on the ventral side of the last abdominal segment a cross comb of a few short hairs.

Host trees. Stone fruit, pome trees, and some other Rosaceae. Of the fruit trees it infests primarily peach and quince, and secondarily apricot, plum, almond, pear and apple. It is widely distributed in the palaearctic and nearctic regions.

Life history and damage. It is considered to usually complete 5-6 generations per year in Greece. Damos and Savopoulou-Soultani (2010a), in central northern Greece, based on male moth catches in pheromone traps, accept at least 3 generations, but had difficulty in defining discrete generations, especially after the 2nd male moth flight. They point out that bimodality occured in some of their moth flights, as also observed in California by Rice et al. (1984). Damos and Savopoulou-Soultani (2010a) do not exclude the possibility that those larvae of the 3rd gerneration that did not enter diapause, pupated in the same year and gave the adults of the 4th flight. Their moth catches were low early in the season, kept increasing as the season progressed, and became highest during August and September. In Italy up to 5 generations have been reported (Zangheri et al. 1992). In cooler climates the number is smaller, such as 2 in Germany and 3 in

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Slovenia (Tomse et al. 2004). It overwinters as grown larva under dry bark, in fissures of the trunk and in other refuges. The adults of the generation that overwintered appear in spring, when the development of the leaf buds of peach starts. They oviposit on leaves and on young shoots. The neonate larva enters a new shoot, at a point near its tip and bores a gallery along the central axis of the shoot. The gallery may be as long as 4-6 cm. The apex of the shoot withers and dies. To complete its growth the larva may enter and destroy more than one shoot tip. This kind of injury is considerable in young trees, but not in grown trees. When the larva of the first generation completes its growth as a stem borer, it abandons its gallery and pupates in fissures of the bark and at other protected sites. The adults of the following generations oviposit on leaves, shoots, pedicels or fruits. When the shoots are still tender, the larvae enter their apical part and develop as stem borers. As the season progresses and the shoots harden, the larvae feed for a short time on apical buds, and subsequently on green fruits superficially. Later, when the fruits approach maturity, the larvae bore galleries towards the inner layers of the mesocarp, near the endocarp. There they complete growth, feeding on the mesocarp, even after the fruit has been harvested. In southern Europe, the generations overlap from mid-May on. The symptoms of the infestation of shoots and fruits resemble those caused by *Anarsia lineatella* (see above). In the almost ripe or in the ripe fruits the larval entrance hole is not easily discernible, especiaslly if it was done by a first-instar larva. Usually the entrance hole is near the pedicel or at a point of contact of the fruit with some other solid plant surface. Therefore, at harvest the infestation is not externally perceivable.

This insect is considered one of the most serious pests of peach and quince in most countries with a mild continental climate. If it is not controlled in time, damage especially to late peach cultivars is considerable. Of quince trees it infests mainly the fruits at any stage of development. Of almond trees it infests almost exclusively the shoots, and of pear trees the fruits of late cultivars.

Zangheri et al. 1992) give the names of hymenoptera which parasitize this insect, including *Macrocentrus ancylivorus* Roh., introduced from the United States to biologically control the moth. Yet, control by natural enemies has not proven sufficient.

Control. A winter spray of the trunk and limbs, kills a certain percentage of overwintering larvae. This spray, like the one against *Anarsia lineatella,* is done with an oil emmulsion (summer oil for

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peach, and winter oil for the other deciduous trees), or with an organophosphorous insecticide, or with a combination of the two. The winter spray should cover also the installations and materials where packing of peaches or other infested fruits has been done (Anonymous 1973). During the growing season, the insecticidal applications aim at the simultaneous control of *A. lineatella,* which as a rule co-exists with *G. molesta.* A spray used to be recommended in late March with certain synthetic organic insecticides against *A. lineatella,* and two or three in May and June with certain organophosphorous insecticides, or an insect growth inhibitor. In June closer to harvest, carbaryl and fluvalinate, considered among the least hazardous ones were also used (Kyparissoudas 1989a, b). For both species of moth, the population is followed using pheromone traps or in other ways, and instructions are given to fruit growers by the Plant Protection Warning Services as to the proper dates to spray and the proper insecticides to use. Damos and Savopoulou-Soultani (2010a) after male moth captures in pheromone traps in peach orchards of central northern Greece, recommend a model concerning the times of flight of male moths of the three major moth species infesting peach. A brief reference to that work has been made in the text on *A. lineatella* (above). It is advisable for pest control advisers and progressive fruit growers to consult that paper. In California, insecticide treatments were targeted at or near the peak of moth flight of any given generation of *G. molesta.* To determine the optimum spray timing in Sacramento and San Joaquin valley orchards of that state, Rice et al. (1984) used pheromone trap data together with a phenology model based on degree-days. Highest levels of larval control were obtained with diazinon at 600 degree-days after the beginning of the 2nd moth flight, followed closely in effectiveness by a treatment applied at 500 degree-days. An insecticide with a greater residual action such as azinphosmethyl, showed no differences at 400-700 degree-days. The fewest twig strikes were recorded in the 500 and 600 degree-days treatments “into the flight”. Accuracy allowed the use of shorter residual, therefore milder, insecticides effectively. An experimental application of the mating disruption method with pheromone evaporators in peach orchards of northern Greece, gave promising results (Kyparissoudas 1989a). The method was found satisfactory also in Italy and some other countries (Cravedi et al. 1991 and references therein).

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Euzophera bigella **Zeller** (possibly *E. egeriella* Mill.), **(Lepidoptera, Pyralidae)**, comm. **fruit pyralid, tignola subcorticale**

Adult. It has a wing span of 15-18 mm. The forewings are brown-grey, with one whitish transverse sinuous stripe near their middle and another more oblique towards the apex. The information below regarding this moth is based on the publications of Deseö (1980) and Zangheri et al. (1992).

Larva. Fully grown it is 10-12 mm long. The color varies but is more frequently greyish, with the head light brown and the prothoracic shield dark brown. When young, the larva can be mistaken for that of the codling moth, because both have a dark prothoracic shield. However, the larva of *E. bigella* retains the light brown head and the dark brown prothoracic shield throughout the larval stage, and at the L4 its body has become grey, more or less dark, whereas the codling moth larva is light or dark pink. On the other hand, the larva of *G. molesta* has a light brown to yellow prothoracic shield (Deseö 1980).

Host trees. Many in respect to subcortical feedings, including olive (Silvestri 1942). Infestation of fruit during maturation is more frequent in stone and pome fruits.

Life history and damage. This moth is reported more frequent in West Asia including Asia Minor, but also occurs in all southern Europe. In Italy harmful infestations have been reported especially in the center and the north. Not much about its life history is known in Europe. The following concerns Italy, where it is reported bivoltine. It overwinters as grown larva. It pupates from early April to mid-May. The adults are seen from late April to the end of May. The eggs of the first generation are seen from the second decade of May to mid-June and those of the second generation from early July to late September. Thus, there is an overlapping of the larvae of the two generations, and a continuous presence of larvae during the season that stone and pome fruits start maturing or are mature, therefore apt to infestation. Fully grown larvae in autumn will enter dormancy and overwinter. The young larva may enter the fruit near the pedicel, under the calyx, and from wounds. Thus, infestation is difficult to detect from the outside.

It seems that the larvae can develop to full growth feeding on parts of rotten bark. Such infestation of woody parts of the trees is not considered especially harmful. The young larva may feed superficially

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on fruit skin and sooty mold, but does not enter and cannot develop inside unripe fruits. Fruits are entered only during the phase of maturation and when mature. Ripening or ripe apricots, peaches, pears, apples and quinces can be infested. The injury continues to the storehouse, temperature permitting. In the orchard in Italy, injury to fruits started in July, was aggravated in August, and continued throughout September. Symptoms of fruit infestation resemble in part "embroidering" and in part those caused by *Grapholitha molesta, Anarsia lineatella, Cydia pomonella* and *Lobesia botrana.* In peach orchards of Emilia-Romagna *E. bigella* was sometimes as harmful as *G. molesta* and apparently more important as a pest than *A. lineatella* (Deseö 1980). Specific control recommendations will await the detailed study of its life history in European orchards.

Some other leaf-feeding Lepidoptera

The leaf-feeding Lepidoptera that infest stone fruit and pome trees are many. In this section we give seven species which are encountered often in stone fruit and some also in pome fruit trees, but usually in not dense, therefore, not damaging populations. *Yponomeuta padellus* L. (Yponomeutidae) resembles so much *Y. malinellus* which infests apple (Figs. 98-101), that it is often mistaken for it. *Y. padellus* infests usually plum, more seldom almond, cherry and *Crataegus,* and very seldom apple and *Sorbus* (Martouret et al. 1966). It also has one generation per year and overwinters, lives, attacks its host trees, and is controlled in the same way as *Y. malinellus.* In Europe the cherry tree is infested also by the related species *Y. evonymellus* L. In *Hedya pruniana* Hübner (Tortricidae) the adult resembles much in color and shape *H. nubiferana* (see pome fruit insects) but it is a little smaller, and usually has a dark spot in the middle of the white apical part of its forewings. It infests mainly stone fruit trees and less often pome trees. The larva also resembles in color, size and feeding habits that of *H. nubiferana. Aporia crataegi* (L.) (Pieridae) has adults with white or whitish wings with black veins (Figs. 180, 181), and larvae of a dark color, almost black. It completes one generation per year. It overwinters as a young larva in a group nest on the tree. It infests various Rosaceae and more often apple and pear. *Diloba caeruleocephala* (L.) (Noctuidae) is univoltine and has larvae with blue head (Fig. 182). It diapauses in summer in the pupal stage, and in winter in the egg stage (Tzanakakis and Koveos 1983). It infests

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Figs. 180-181. *Aporia crataegi.* 180.Adult. 181.Pupa (photo B.I.K.).

Fig. 182. Larva of *Diloba caeruleocephala.* Its head is not seen (photo B.I.K.).

Figs. 183-184. *Vanessa polychloros.* 183.Adult. 184.Erosion by larvae of foliage of wild pear (photo B.I.K.).

cultivated and wild Rosaceae, and quite often the ornamental plum *Prunus pissardii.* The adult forewings are dark brown with three blueish circular or reniform spots close to one another in the center of each wing. For details in morphology of all stages see Ciampolini (1948). *Iphiclides (Papilio) podalirius* L. (Papilionidae) infests various Rosaceae with preference on *Prunus*. The adults are impressive (Fig.

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Fig. 185. *Iphiclides podalirius* adult (photo B.I.K.).

185), with relatively large wings. The larvae are dull green, with oblique yellow lines. It completes 2 generations per year (see Tzanakakis 1980). *Vanessa (Nymphalis) polychloros* (L.) (Nymphalidae) has adults with beautiful red-brown wings, with black, brown-red and blue spots (Figs. 183, 184). The larvae are of a dark color, almost black, with spinelike tubercles, and live in groups. It infests preferably cherry and wild cherry (see Isaakides 1936a, Anagnostopoulos 1939). It usually does not cause considerable damage, however, erosion of 80% of the foliage was observed in two relatively small cherry trees of the Aristotelian University Farm near Thessaloniki in 1982 (B.I. Katsoyannos, personal observation).

Caliroa cerasi **(L.)** *(C. limacina, Eriocampoides limacina, Tenthredo aethiops, T. cerasi)* **(Hymenoptera, Tenthredinidae)**, comm. **pear slug**

Adult. Scognamiglio (1954) gives details of the morphology and drawings of all life stages of this species which he studied in southern Italy. According to him, both sexes are shiny black, with transparent slightly smoky wings (Fig. 186). The adult female has black compound eyes and red ocelli. It is 6-6.5 mm long, and has a wing span of 12 mm. The male is smaller, 4-4.5 mm long, with a wing span of 9-10 mm. Anagnostopoulos (1939), probably referring to specimens from Greece, gives the adult length 4-5 mm, without specifying the sex. Other sources give the female as 5-6.5 mm long, with a wing span of 10-11 mm.

Egg. Oval, whitish or yellowish, approximately 0.5 mm long, or

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according to Scognamiglio (1954) longer, up to 0.83 mm.

Larva. It has 3 pairs of thoracic legs and 7 of abdominal prolegs, and a final length of 10-12 mm. It is yellow-green, but produces a black or almost black slime which covers its body from the 2nd or 3rd day of life to the end of the penultimate larval stadium. The common name of this insect is due to this slimy substance, which smells like ink, and makes the larva resemble a slug (Fig. 186c). After the last molt the larva does not produce the slimy substance, neither feeds, but enters the soil to spin the cocoon in which to pupate.

Host trees. Usually cherry and pear, and more seldom other cultivated or wild Rosaceae. It occurs in almost the whole of Europe where its host trees grow, as well as in Asia Minor, Central Asia, North and South Africa, the Americas, and Australia.

Life history and damage. In some countries like France the males are few compared to the females, therefore, reproduction is mostly parthenogenetic (Balachowsky and Mesnil 1935). In other countries like Italy, the adult males were approximately as numerous as the females (Scognamiglio 1954 and references therein).

It is reported to have 2 generations per year in Greece, Italy, France, Algeria and California, and only one in certain parts of Canada (Anagnostopoulos 1939, Balachowsky and Mesnil 1935, Scognamiglio 1954 and references therein). It overwinters in the soil in a parchment-like cocoon, according to certain authors as grown larva, and according to others as pupa. The adults emerge in spring, when the first leaves of pear have developed. The female, using its saw-like ovipositor, cuts the lower leaf surface and inserts one, and more seldom 3 or more eggs, in each leaf. The egg is inserted between the parenchyma and the upper epidermis. The larvae eat the upper epidermis and the parenchyma, leaving the veins and the lower epidermis, thus skeletonizing the leaf (Fig. 187). A larva can pass easily from one leaf to another, and may consume 4 or more leaves until full growth. The larvae of the 2nd (summer) generation attack the leaves in a similar way, then drop to the soil spin a cocoon and remain there as larvae or pupae until the following spring. According to Anagnostopoulos (1939), the eggs of the first generation are inserted in the leaves in April-May and of the 2nd one in July-August. The larvae hatch in approximately 2 weeks. In Mikra, near Thessaloniki, on young cherry trees, the last grown larvae of the first generation were seen in late July, the first young larvae of the 2nd generation in late August, and the last fully

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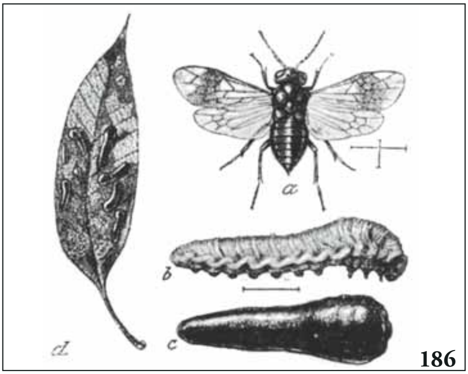

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Figs. 186-188. *Caliroa cerasi.* 186a adult, b larva without the slimy cover, c with the slimy cover, d pear leaf with larvae and erosion they made (Staz. Firenze).187. Cherry leaf sceletonized by larval feeding (photo B.I.K.). 188.Last instar larva on an infested cherry leaf (photo B.I.K.).

grown larvae in late September to mid-October (S. Verras and M.E. Tzanakakis, unpublished data). In southern Italy, depending on the year, the first adults of the overwintering (2nd) generation appeared from late April to mid-May, and those of the next (first) generation in late June to early July (Scognamiglio 1954). In the Paris area, the first-generation larvae are seen from the end of May to mid-July and those of the second one are seen from mid-August to mid-October, and are abundant in September (Balachowsly and Mesnil 1935).

When the insect's populations are dense, the trees, especially young ones, may lose all their foliage. However, effective natural enemies, or insecticides used against other insect pests of cherry and pear, usually reduce the populations of *C. cerasi* to tolerable levels.

Control. A spray with a stomach insecticide or a selective contact one, usually organophosphorous, is recommended as soon as an alarming larval population is observed, especially of the first generation.

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Other leaf-feeding Hymenoptera

In addition to *Caliroa cerasi,* certain other Hymenoptera of the same suborder (Symphyta) have leaf-feeding larvae which infest more often almond and peach, and less often other stone fruit trees. The larvae eat the lamina of the leaf, leaving usually the midvein and the petiole. In certain years defoliation can be serious. Of these species, *Palaeocimbex quadrimaculata* (O.F. Mueller) has the largest body. The adult female is black or dark brown with yellow spots and stripes, and 20 mm long. The larva (Fig. 189) is at first grey-blue and later green with dark spots, and has a final length of 40 mm (Anagnostopoulos (1939). It infests usually almond and more seldom peach. *Neurotoma nemoralis* L., infests more often peach. The adult is black, 8 mm long, and the larvae green (Anagnostopoulos 1939). Also of relatively small size are *Arge melanochroa* Gmelin, *A. proxima* André, and *A. scita.* On the island of Skopelos a few decades ago, the senior author (unpublished data) observed complete defoliation of a non-irrigated almond orchard by larvae of a species of *Arge* (Fig. 190). The species *A. rosae* (L.) and *A. pagana* Panzer which occur also in Greece, feed on the foliage of roses (*Rosa* spp.). Effective natural enemies usually maintain the populations of these Hymenoptera at tolerable densities. If erosion of the foliage in spring suggests control, a spray with a contact or even a stomach insecticide is recommended.

Fig. 189. *Palaeocimbex quadrimaculata* larva on an almond leaf (photo B.I.K.).

Fig. 190. Complete defoliation of an almond tree by larvae of a species of *Arge,* on Skopelos island (photo M.E.T.).

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Hoplocampas of plum (Hymenoptera, Tenthredinidae)

Three species of this genus have often been reported as infesting plum in southern Europe: *Hoplocampa minuta* Christ., known as the black hoplocampa of plum, *H. flava* L., known as the yellow hoplocampa of plum (Figs. 191, 192), and *H. rutilicornis* Klug. They

Figs. 191-193. *Hoplocampa flava.* 191. Adult (photo A. Staub). 192.Larva and its dark feces in an infested plum (photo A. Staub). 193.Young plums infested by a species of *Hoplocampa* (photo B.I.K.).

are univoltine, and have similar life histories. The first two are the most common in central Europe. The adult of *H. minuta* is shiny black, with transparent wings, and is 3-4 mm long. It infests young fruits of plum. It overwinters as fully grown larva in a brown cocoon in the soil. The adult appears a little before and during the blooming of plum. It inserts an egg, and more seldom 2-4 eggs, in the outer layer of the calyx of flowers (Anagnostopoulos 1939, Della Beffa 1961). The larva hatches when the young fruit has formed, enters the ovary where it bores a small gallery and destroys the ovary. Subsequently, it enters a neighboring fruit where it also bores a gallery (Fig. 193), and causes its drop. A larva can thus destroy 4-5 fruits until it reaches full growth. When it has completed growth, it enters the soil where it spins a cocoon in which it remains until the following spring.

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The first two species are controlled with insecticidal sprays applied before bloom and when three fourths of the petals have fallen. *H. rutilicornis* has been reported by Roberti (1949) as the most spread hoplocampa on plum in the Campania region of southern Italy. Its larva may destroy 3-4 fruits until it reaches full growth in mid-April.

Eurytoma amygdali **Enderlein (Hymenoptera, Eurytomidae)**, comm. **almond seed wasp, eurytoma of almond**

Adult. The male is 4-6 and the female 6-8 mm long. The body is shiny black and the legs of a lighter color. In dorsal view the head and thorax are relatively wide, and the abdomen spindle-shaped and narrower than the thorax. The wings are transparent, with a small brown spot (Figs. 194).

Egg. Whitish, with a long stalk.

Larva. It is white, apodous, stout, thicker in the middle, and in side view curved, with a small brown head retracted almost completely in the prothorax (Fig. 195). Its final length is 6-9 mm.

Pupa. Free, white, 5-7 mm long, in a loose cocoon, inside the fruit.

Host trees. Almond only. Older views that it also infests apricot and plum are not correct.

Life history and damage. Most of the population completes one generation per year, while a smaller proportion completes a generation in 2 or 3 years. For details on seasonal development and control in northern Greece see Mentzelos and Atzemis (1968), B. Katsoyannos and Kouloussis (1991), B. Katsoyannos (1997), and references therein. It overwinters as fully grown larva in the infested almonds, which usually remain mummified on the tree and less often fall to the ground (Fig. 196). It pupates in late winter to early spring and becomes adult in spring. To come out of the mummified fruit, the adult opens with its mandibles a circular 1-2 mm hole in the pericarp (Fig. 197). The males emerge 2-3 days before the females and the ratio of males to females in the Thessaloniki area is 1:2 (B. Katsoyannos and N. Kouloussis unpublished data). In northern Greece the adults appear on the foliage of the trees when the petals of late-blooming almond cultivars have fallen. At that time, in most almond cultivars fruits have set. Mating occurs the first days of adult

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Figs. 194-198. *Eurytoma amygdali.* 194.Adult during oviposition (photo B.I.K.). 195.Fully grown larvae inside almonds (photo N.A. Kouloussis). 196.Mummified almonds containing larvae in winter. 197.Exit holes of adults in Retsou almonds in spring. 198.Gum at the wasp's oviposition sites on Retsou almonds (photo B.I.K.).

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life and the female soon begins to oviposit. Of its approximately 150 stalked eggs, it inserts usually one egg per fruit. The endocarp is then soft and allows the penetration of the ovipositor. The ovipositor penetrates the pericarp and the perisperm, and the egg is placed inside the endosperm (then spermatic tissue) (Fig. 200). The oviposition hole is not discernible on the epicarp. In certain cultivars, such as Retsou, gum comes out and indicates the point of the oviposition hole (Fig. 198). In all cultivars, a red-brown little spot is formed on the perisperm and the inner surface of the endocarp. Also, a small tumor of an approximate height of 1 mm is formed on the inner surface of the endocarp. From a few days to 3 weeks from oviposition the young larva hatches. It grows feeding on the embryo (cotyledons) without touching the perisperm, as a rule. Therefore, the larva destroys the commercial part of the almond fruit. It completes its growth in late June to mid-July and remains in diapause inside the infested fruit. The proportion of the larval population which does not develop to the adult stage the following spring but remains in diapause for more than a year, varies with the region, the year and the cultivar of the tree.

In most cultivars, the almonds that contain grown larvae remain on the trees, become mummified, are often of dark color, retain their mesocarp in place, therefore do not dehisce, and do not fall off the tree at harvest time in autumn (Fig. 196). Consequently, after leaf fall it is easy to distinguish the infested fruits and estimate the extent of damage. Under high population density, the percentage of oviposited fruits of certain susceptible cultivars such as Retsou, may approach or even reach 100%. In such cases the yield is annihilated or is very small, as most eggs give larvae that survive and destroy the fruits. In some cultivars such as Texas (Mission) most of infested fruits drop early, usually in late May. This early fruit drop in the cultivar Texas may surpass 90%, as we have recorded on the Aristotelian University Farm (Tzanakakis et al. 1997). This early drop, added to that of infested fruits that do not fall early, virtually annihilates the yield. The early fruit drop in Texas trees used to be attributed to other causes, and no measures against the adult seed wasp were taken to limit it. Generally, damage by *E. amygdali* can be serious, therefore, this insect is reasonably considered as the most serious insect enemy of almond in Greece.

Control. An effective measure is to collect and destroy, usually by fire, the mummified fruits which remain on the tree and contain

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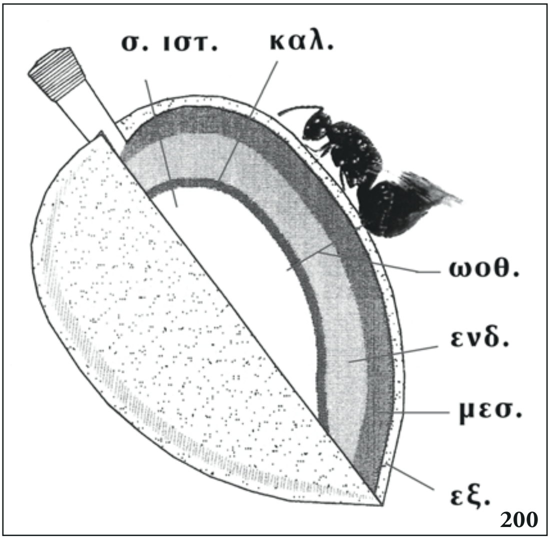

Fig. 200. Section of the pericarp and seed of an almond the period of oviposition of the almond seed wasp, and a female in position of laying (diagrammatically).
ενδ: endocarp
εξ: exocarp
καλ: seed covers
μεσ: mesocarp
σ. ιστ: spermatic tissue
ωοθ: female ovipositor
(Kouloussis 1993).

grown larvae. This can be done together with the picking of healthy almonds at harvest time, or later in autumn or winter. This measure is effective when no untreated almond trees are in neighboring orchards, and when it is applied in all almond trees of as large an area as possible. However, because most growers seldom take this measure, control of the insect is usually done with insecticides. Systemic organophosphorous insecticides, such as phospohamidon were used for a number of years, the purpose being to kill the young larvae inside the fruits. Work over eight years in the area of Thessaloniki by B. Katsoyannos and collaborators showed that a single treatment with a systemic insecticide sufficed, if applied to fruit-bearing branches of the Retsou cultivar when the percentage of hatching of larvae from the eggs was between 10% and 50% (B. Katsoyannos et al. 1992, B. Katsoyannos 1997). These percentages occurred approximately 21 and 27 days respectively after the beginning of male adult captures in sex pheromone traps, each containing 25 virgin female wasps (Fig. 201). Those females release the attractive sex pheromone. The emergence of adults from mummified almonds of the previous year was also monitored in cages in the field installed in late March at a small height (Fig. 202). Almond growers do not cage infested almonds to determine when to spray. In cultivars such as Texas, where oviposited fruits undergo a heavy early drop, killing of the young larvae inside

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Figs. 201-202. *Eurytoma amygdali.* 201.Base of a pheromone trap having an attractive cage with virgin females, and captured males on the sticky (white) surface around it. 202.Cage with mummified almonds, to follow the time of exit of the adult wasps (photo B.I.K.).

the oviposited fruits does not protect the crop. In such cultivars insecticides to kill the adults before they oviposit are needed.

Today only a wide spectrum long-lasting synthetic pytethroid such as deltamethrin is permitted on almond trees against this seed wasp in Greece (Kouloussis 2013). This pyrethroid acts by contact, and is aimed at killing the adults during the 3-4 weeks they are active in the orchard, before they oviposit. Only two applications of deltamethrin are permitted per season, the first one when the adults appear, and the second 2 weeks later (Kouloussis 2013). In France one spray with another pyrethroid, l-cyhalothrin, at the beginning of the adult flight was sufficient to protect the crop. However, as Kouloussis (2013) points out, verification of the sufficiency of only one insecticidal spray in Greece is needed, as well as further research to achieve incorporation of the control of this wasp into an IPM program for almond orchards.

After the isolation, identification and chemical synthesis of the major components of the female sex pheromone of this wasp have been achieved, the two major components, (Z,Z)-6,9-tricosadiene and (Z,Z)-6,9-pentacosadiene, chemically synthesized, were tested by Mazomenos et al. (2004) in rubber septa attached to adhesive cardboard traps in an almond orchard in eastern central Greece. Either alkadiene was attractive to male wasps, but the 7:3 ratio of them gave the maximum attraction. It is hoped that further improvements in this trapping technique together with the commercial availability of

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these chemicals at a reasonable price, will provide an effective method of monitoring the adult wasp population to determine the optimum time for insecticide applications, and possibly for mass trapping the male wasp population. Such pheromone components are not yet available on the market (Kouloussis 2013).

Eurytoma schreineri Schreiner (Hymenoptera, Eurytomidae)

This seed wasp was recorded for the first time in southern Greece, infesting apricots (Koveos et al. 2000, 2002). Time will show how fast it may spread in the country, on which host trees and how injurious it may become. In other countries it infests apricots, cherries, plums and blackthorn fruits. For many years it was referred to as *E. amygdali* until Nikolskaya (1961) distinguished it as a different species. Koveos et al. (2000, 2002) give adult characters taken from Zerova and Fursov (1991) distinguishing this species from other seed wasps infesting stone fruits. Koveos et al. (2000) give also photographs of adults of both sexes in dorsal and side view (Figs. 203, 204), photographs and drawing showing differences in the abdomen of this species from that of *E. amygdali* (Figs. 208, 209), small-size infested versus normal size uninfested apricots (Fig. 205), and larvae inside infested fruits (Fig. 206). In Ukraine this wasp is univoltine and this is most probably the case elsewhere. Its seasonal development in Greece has not yet been investigated.

Other anthophagous, phyllophagous, and carpophagous species

A number of species of the beetle families Scarabaeidae and Curculionidae that are, in the first pages of each chapter, on the lists of species infesting pome and stonefruit trees and grapevine but not treated to some extent in the text of the book, may occasionally cause damage as adults by defoliating trees or consuming flowers or fruits, especially in spring or early summer. They are semicyclic, monocyclic, or oligocyclic, depending on the species, the region, and the host tree. Their larvae live in the soil or in dung and are rhizophagous and/or saprophagous. When large numbers of adults are seen on the foliage, or erosion of leaves, flowers or fruit is substantial, prompt control

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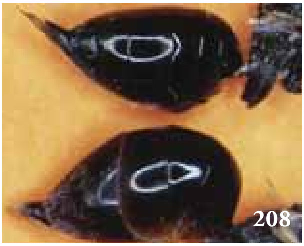

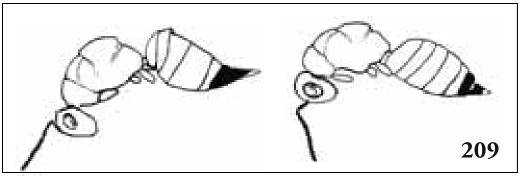

Figs. 203-209. *Eurytoma schreineri.*
203.Adult female above and male below in dorsal view.
204.Male left and female right (Koveos et al. 2000).
205.Reduced size infested apricots at harvest time above, and normal size uninfested ones below
206.Grown larvae inside cut-open apricot stones and eroded seeds (Koveos et al. 2000).
207.Endocarps (stones) of apricots with exit holes of adults (Koveos et al. 2000).
208.Abdomen of *E. schreineri* above, and *E. amygdali* below, in side view (Koveos et al. 2000)
209.Drawings of *E. amygdali* left, and *E. schreineri* right, to show differences in abdominal tergites (Koveos et al. 2002, redrawn from Zerova and Fursov 1991).

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with a contact or stomach insecticide is advisable.

Two of those species are seen in figs. 210 and 211. According to Isaakides (1936a) *Epicometis hirta* (*Cetonia hirtella*) is semicyclic. Its adults feed on the stamens of citrus, other fruit trees, grapevine and ornamentals. *Melolontha melolontha* was harmful in middle and northern Europe in old days. Its adults are exteremely polyphagous, feeding on various fruit trees and broadleaved forest trees. Their root-feeding larvae used to injury annual crops. Its life cycle is completed in 3 years in southern and 4-5 years in northern Europe.

Fig. 210-211. 210.*Epicometis (=Tropinota) hirta* adult (A.U.T.).
211.*Melolontha melolontha*. Adult male left and female right (Calwer 1893).

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Insects of citrus trees

Homoptera

Planthoppers

- *Metcalfa pruinosa* (Say), Flatidae

Aleyrodoidea (whiteflies)

- *Aleurothrixus floccosus* (Maskell), Aleyrodidae
- *Dialeurodes citri* (Ashmead), Aleyrodidae
- *Parabemisia myricae* (Kuwana), Aleyrodidae

Aphids

Aphis craccivora Koch, Aphididae
Aphis fabae Scopoli, Aphididae
Aphis gossypii Glover, Aphididae
- *Aphis spiraecola* Patch, Aphididae

Aulacorthum solani (Kaltenbach), Aphididae
Brachycaudus helichrysi (Kaltenbach), Aphididae
Macrosiphum euphorbiae (Thomas), Aphididae
- *Myzus persicae* (Sulzer), Aphididae
- *Toxoptera aurantii* (Boyer de Fonscolombe), Aphididae
- *Toxoptera citricida* (Kirkaldy), Aphididae

Coccoidea (scale insects)

- *Aonidiella aurantii* (Maskell), Diaspididae
- *Aspidiotus nerii* (Bouché), Diaspididae
- *Chrysomphalus aonidum* (L.), Diaspididae
- *Chrysomphalus dictyospermi* Morgan, Diaspididae

Chrysomphalus ficus Ashmead, Diaspididae
- *Lepidosaphes beckii* (Newman), Diaspididae
- *Lepidosaphes gloverii* (Packard), Diaspididae
- *Parlatoria oleae* (Colvée), Diaspididae

Parlatoria pergandei Comstock, Diaspididae
- *Parlatoria ziziphi* (Lucas), Diaspididae
- *Ceroplastes floridensis* Comstock, Coccidae

Ceroplastes japonicus Green, Coccidae
- *Ceroplastes rusci* L., Coccidae
- *Ceroplastes sinensis* Del Guercio, Coccidae
- *Coccus hesperidum* L., Coccidae
- *Coccus pseudomagnoliarum* (Kuwana), Coccidae

Chloropulvinaria floccifera (Westwood), Coccidae
Protopulvinaria pyriformis (Cockerell), Coccidae
- *Saissetia oleae* (Bernard), Coccidae
- *Planococcus citri* (Risso), Pseudococcidae
- *Pseudococcus adonidum* (L.), Pseudococcidae

Pseudococcus longispinus (Targioni-Tozzetti), Pseudococcidae
- *Pseudococcus viburni* (Signoret), Pseudococcidae
- *Icerya purchasi* Maskell, Margarodidae

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Hemiptera

- *Calocoris trivialis* Costa, Miridae
  Graphostethus servus F., Lygaeidae
  Nezara viridula (L.), Pentatomidae

Thysanoptera (thrips)

- *Frankliniella occidentalis* (Pergande), Thripidae
- *Heliothrips haemorrhoidalis* (Bouché), Thripidae
  Melanthrips fuscus (Sulzer), Thripidae
  Neohydatothrips burungae (Hood),
- *Pezothrips kellyanus* (Bagnall), Thripidae
  Scirtothrips aurantii Faure, Thripidae
- *Scirtothrips citri* (Moulton), Thripidae
  Scirtothrips dorsalis Hood, Thripidae
- *Scirtothrips inernis* Priesner
  Thrips atratus Haliday, Thripidae
  Thrips flavus Schrank, Thripidae
  Thrips major Uzel, Thripidae
  Thrips meridionalis Priesner, Thripidae
  Thrips tabaci Lindeman, Thripidae

Coleoptera (beetles)

- *Epicometis hirta* (Poda), Scarabaeidae
  Oxythyrea funesta Poda, Scarabaeidae
  Tropinota squalida (L.), Scarabaeidae
  Carpophilus hemipterus L., Nitidulidae
  Apate monachus F., Bostrychidae
- *Sinoxylon sexdentatum* Olivier, Bostrychidae

Diptera

- *Ceratitis capitata* (Wiedemann), Tephritidae

Lepidoptera

- *Archips rosanus* L., Tortricidae
- *Cacoecimorpha pronubana* Hübner, Tortricidae
- *Cryptoblabes gnidiella* Millière, Pyralidae
- *Ectomyelois ceratoniae* Zeller, Pyralidae
- *Ephestia vapidella* Mannerheim, Pyralidae
  Gymnoscelis pumilata Hübner, Geometridae
- *Phyllocnistis citrella* Stainton, Gracillariidae
- *Prays citri* Millière, Hyponomeutidae
  Tephroclystia pumilata (Hübner), Geometridae

The most important insect enemies of citrus trees in Greece and in other Mediterranean countries are the Mediterranean fruit fly, certain species of Homoptera, namely whiteflies, aphids, and scale insects, and the citrus flower moth. For many of the Homoptera pests there are effective natural enemies, parasitoids or predators, which are able

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to control the pest populations under certain conditions. Therefore, integrated control is the advisable strategy for the protection of citrus trees. Against whiteflies and scale insects and less so against aphids, entomophagous insects are used, and in exceptional cases selective insecticides. Against the Mediterranean fruit fly, mainly bait sprays and mass trapping are usually applied, while against the citrus flower moth selective insecticides. For ways of sampling, economic injury levels, and intervention thresholds for the main insect and mite enemies of citrus trees, see the reviews by P. Katsoyannos (1996), Jacas et al. (2010), Karamaouna et al. (2010), and references therein. As Jacas et al. (2010) mention in their review, IPM guidelines are defined at regional level in Greece, Portugal and Turkey, and at both regional and national level in Israel, Italy and Spain. Guidelines for integrated production of citrus have been produced by the IOBC/WPRS Commission in 2004. They mainly concern standards for the integrated production organizations in order to develop national and local guidelines. According to these standards in their review of the subject, preventive measures must be applied before direct control techniques are used. Priority should be given to natural, cultural, biological, genetic and biotechnical methods, the use of agrochemicals to be minimized. Pesticides must be classified by the IP organizations into “green list”, i.e. permitted, and “yellow list” i.e. permitted with restrictions. Such classification is based on several criteria, such as human toxicity, toxicity to key natural enemies, other organisms, pollution of ground and surface water, ability to stimulate pests, selectivity, persistence, necessity, incomplete information. Jacas et al. (2010) give a list of species of insects and mites recorded in northern Mediterranean regions (modified from Franco et al. 2006), a list of visual inspection practices by season for citrus IPM, and a list of insecticides, acaricides and insect attractants registered for use on citrus in Spain, Italy and Greece (as of June 2008).

Metcalfa pruinosa **(Say)** (*Flata ormenis, F. pruinosa*) **(Homoptera, Flatidae)**, comm. **citrus flatid planthopper**

This is a polyphagous planthopper of north American origin, which invaded Europe in the last few decades. In Italy it was observed in 1979 in the Treviso (Veneto) area (Zangheri and Donadini 1980). By 2004 it had spread to southern France, Corsica, Switzerland, Slovenia and Croatia, whereas in 2001 and 2002 is was recorded on olive and

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citrus in Greece (Drosopoulos et al. 2004).

Adult. According to Zangheri and Donadini (1980), it is 7-8 mm long (probably wings included) and has the characteristic shape of most flatids. The hemielytra (forewings) are trapezoid, dark grey-brown and covered, not uniformly, with a waxy secretion of lighter color.

Larva. The neonate larva is whitish, and later becomes slightly greenish. The fully grown one is approximately 3.5 mm. The larva is covered with abundant waxy secretion.

Host plants. This flatid is most polyphagous. Only in the Veneto area of Italy, it was recorded on 40 different plant species. Among them grapevine, citrus, avocado, fig, pomegranate, papaya, ornamentals such as *Ligustrum ovalifolium,* and the nettle *Urtica dioica.* It can complete its life cycle also on apple, peach, hazelnut, lemon, kiwi fruit (*Actinidia deliciosa*), laurel (*Laurus nobilis), Robinia pseudoacacia, Aesculus hippocastanum, Tilia cordata, Platanus hybrida, Magnolia grandiflora* and roses (Zangheri and Donadini 1980*).* Pomegranate, jasmine (*Jasminum grandiflorum*), bougainvillea and pyracantha are reported as being among its "minor hosts" (Dean and Bailey 1961). A survey in several localities of western and northern Greece in 2005-2006 by Souliotis et al. (2008), recorded it on 16 species of fruit trees including citrus, olive, fig, stone fruits, pear, walnut, actinidia, grapevine, 25 species of ornamental trees shrubs and floricultural plants, tomato, eggplant, and 19 species of weeds.

Life history. It is univoltine. It overwinters as egg on the bark of host trees. For northern Italy, the hatching period of larvae from the eggs starts in early July and continues for a month (Zangheri and Donadini (1980). The newly-hatched larvae undergo a molting, then most of them go to the undersurface of leaves of young shoots. Fewer go to older twigs. The first adults appear in early August. They live for a number of weeks. According to Drosopoulos et al. (2004), there are 5 larval stadia, which in Greece are completed by the end of June. Subsequently the adults appear. The eggs are inserted in the bark of young shoots. Larvae and adults feed on the phloem of plants and produce honeydew which favors the growth of epiphytic fungi. In western central Greece, first-instar larvae hatched from overwintered eggs in late May. Adults were observed from late June to late September (Souliotis et al. (2008).

Under high population density of this planthopper the honeydew causes injury to the host plants similar to that by *Planococcus citri.*

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In northern Greece, considerable damage to kiwi orchards has been recorded by Raptopoulos et al. (2013). Three applications of certain organic insecticides from mid-June to early August were effective against larvae but not adults. In Veneto, Italy, the planthopper was found repeatedly on citrus and grapevine, but did not cause serious damage. Of interest is the observation that in some part of the United States it was abundant on *Celtis laevigata, Ehretia anacua* and purple nightshade growing beneath citrus trees, but not so on the citrus trees (Dean and Bailey 1961). The role of such and other undergrowth in citrus groves and vineyards in affecting this planthopper's population on trees, certainly deserves investigation.

The planthopper's natural enemy *Neodryinus typhlocybae* (Ashmead) was introduced from Italy and released in two areas of Greece (Souliotis et al. 2007). In the first year the percentage of parasitization of the planthopper was approximately 50%. Mass releases of this wasp are also planned.

Aleyrodidae (whiteflies)

Among the species of Aleyrodidae that infest citrus trees, three entered Greece and spread throughout the country in the last few decades. First came *Dialeurodes citri,* second *Parabemisia myricae,* and third *Aleurothrixus floccosus.* Here they are given in alphabetical order, same as most other species of pest insects in the present text. All three species can become serious enemies of citrus under certain conditions, and especially where cultural practices favor them, or effective natural enemies are missing or are annihilated by the use of unsuitable insecticides. The injury these insects cause to the trees is due to the removal of sap and cell contents, as well as to the abundant honeydew they excrete, which favors the development of sooty mold fungi, the latter reducing the photosynthetic capacity of the foliage and soiling the fruits which thus have low commercial value. The wings and the body of adults are covered with a whitish wax powder. These three species are distinguished from one another easily as grown larvae (4th instar), and as adults. They are treated below.

Aleurothrixus floccosus (Maskell) (Homoptera, Aleyrodidae), comm. woolly whitefly

Adult. It is pale yellow and 1.2-1.8 mm long (Fig. 212). When at rest,

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the wings do not cover the abdomen completely, therefore, on dorsal view part of the abdomen is exposed and visible. It flies at short distances.

Egg. It is brown, oval, and slightly curved. While laying a group of eggs, the female keeps its rostrum inserted in a given site of the leaf and gradually turns its body around. Thus, the eggs of each group are usually laid in a circle or an arc of a circle. Subsequently the female moves to another site to likewise lay another group of eggs, and so on (Fig. 213).

Larva. The first instar larva is light brown. After selecting a proper site on the underside of a leaf, it inserts its rostrum to feed, and remains in that site until becoming adult. When becoming second instar, its body is covered, to a limited extent, with woolly wax filaments, and a drop of honeydew. The 3rd and 4th instars as well as the pupa are covered with abundant such wax filaments, hence the name *woolly whitefly* (Fig. 214).

Host plants. It is a polyphagous insect. Its hosts are reported to belong to 18 plant families (Del Bene and Gargani 1991). It is injurious mainly to citrus trees.

Life history and damage. It lives and oviposits on the underside of leaves. In Greece, where it was first observed in 1991, it completes 4-5 generations per year, same as in Sardinia (P. Katsoyannos 1996). On trees within the city of Athens, the overwintering population consisted mostly of 3rd and 4th instar larvae and pupae (P. Katsoyannos 1996, P. Katsoyannos et al. 1997), whereas in a heated greenhouse of Tuscany, Italy, it consisted mainly of eggs and first-instar larvae (Del Bene and Gargani 1991). During the warm part of the year the generations overlap one another, and all developmental stages coexist at any given time, except in winter. In the Zographou part of Athens 6 generations were distinguished, whereas in the cooler suburb of Kifissia five (P. Katsoyannos et al. 1997).

In addition to the removal of nutritive substances from the leaves, the abundant honeydew excreted by larvae and adults favors the establishment of sooty mold fungi which limit the photosynthetic capacity of the foliage, and lower the commercial value of the fruit (Fig. 215). *A. floccosus* is considered a serious enemy of citrus trees.

Control. Control by using only insecticides is not satisfactory. The wax filaments that cover the body of 3rd and 4th instar larvae

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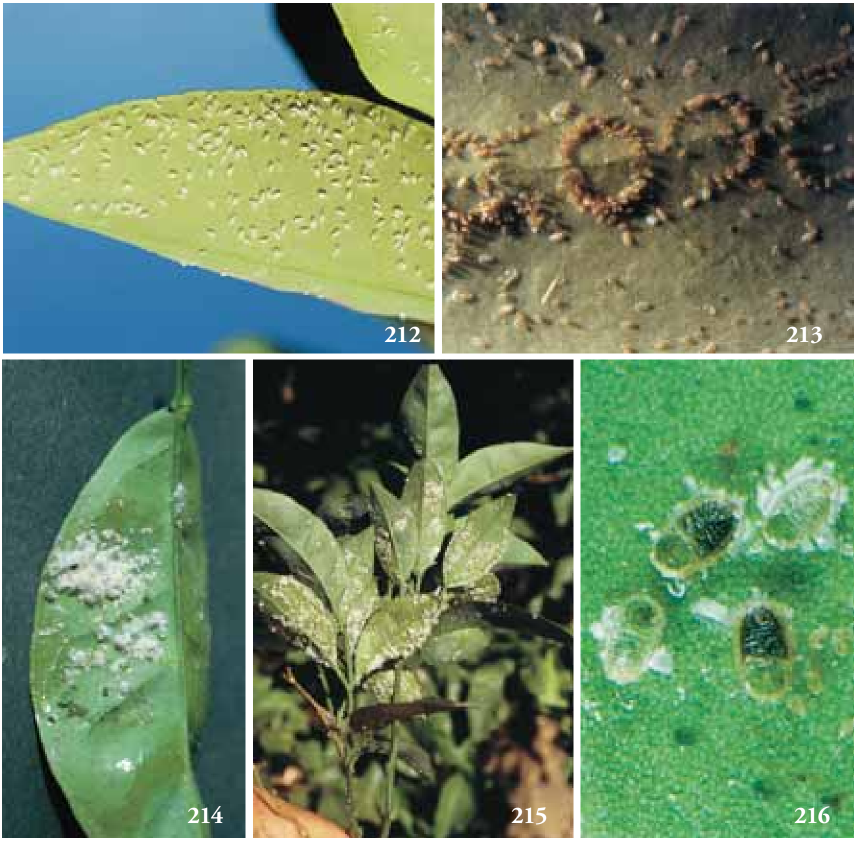
and of pupae impede the penetration of spray liquids. In a number of Mediterranean countries, including Greece, the introduction, rearing, and release of the parasitoid hymenopteran *Cales noacki*



Figs. 212-216. *Aleurothrixus floccosus.* 212.Adults on a leaf (photo B.I.K.). 213. Eggs on a leaf (P. Katsoyannos 1996). 214.Preimaginal stages, wax secretions and honeydew excreted on a leaf. 215.Infested tangerine tree (photo B.I.K.). 216.Dead larvae, with holes of exit of their parasitoid *Cales noacki* (P. Katsoyannos 1996).

Howard (Figs. 217, 216) has limited the populations of this whitefly to a satisfactory degree, and is one of the most impressive cases of successful biological control of an injurious insect. In Athens in 1992, a high population density of 9-11 larvae/cm^2 was brought to only 1-1.7

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larvae/cm^2 mostly by the action of the released *C. noacki.* For details of those first releases of this parasitoid in Athens see P. Katsoyannos

Fig. 217. Adult female of *Cales noacki* (P. Katsoyannos 1996).

et al. (1997a). Fourteen years after the whitefly's introduction to Greece, sampling of infested citrus trees in many localities of the country, showed that the parasitoid wasp continued to keep the whitefly's populations under control (Kontodimas et al. 2005). In Italy, the introduction of a second hymenopterous parasitoid, *Amitus spiniferus* (Brethes) (Platygasteridae), added to the natural control of *A. floccosus* (Zappala 2010). For monitoring the population density of *A. floccosus* by sampling leaves, and using yellow sticky traps, as well as for deciding when to release *C. noacki*, see P. Katsoyannos (1996).

Dialeurodes citri **(Ashmead) (Homoptera, Aleyrodidae)**, comm. **citrus whitefly**

Adult. It is 1.4-1.7 mm long and whitish, because of a white wax powder that covers the body and the wings. Seen from above, the wings cover the abdomen completely (Fig. 218). The head is distinctly narrower than the prothorax.

Egg. Stalked and white, becoming light brown with time. Its apical part is not narrower than the basal one.

Larva. The body is flat and semistransparent, without a waxy perimeter. On its dorsum a yellowish Y is discernible.

Host plants. This whitefly is polyphagous. In Turkey it was found infesting at least 16 species of plants, and adding those recorded in other countries 76 species of plants (Uygun et al. 1990). Among

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them are citrus, pistachio, hazelnut, persimmon, fig, pomegranate, mulberry, and certain ornamental plants.

Life history and damage. In certain areas of Turkey it completes 2-3 generations per year (Uygun et al. 1990). On Corfu Greece, it is considered to complete also 2-3 generations per year (Pappas 1981). It overwinters mainly as a 3rd or 4th instar larva, and as pupa. The adults of the generation that overwintered oviposit on the undeside of young fully developed leaves. Under high population density, eggs have been observed also on old leaves, but not on shoots or fruit. The young larva selects a site on the underside of a leaf, and remains there fixed for the rest of its preimaginal life. In addition to the removal of plant sap, the excreted honeydew favors the development of sooty mold, which soils the foliage and the fruit. A dense foliage and high relative humidity favor the development of dense populations of this whitefly. Where it co-exists with *Parabemisia myricae,* the populations of *D. citri* are usually limited substantially because of competition. In recent years, no serious damage by this whitefly has been reported in Greece.

Fig. 218. *Dialeurodes citri* adult (P. Katsoyannos 1996).

Control. In Turkey, it is controlled with two sprays with summer oils, one in each period of appearance of young larvae, in combination with pruning and controlling the weeds, to reduce air humidity (Uygun et al. 1990). A more effective control is achieved with mass releases of the parasitic hymenopteron *Encarsia (Prospaltella) lahorensis* (Howard*).* In Italy, *E. lahorensis* virtually annihilated the whitefly (Zappala 2010). P. Katsoyannos (1996) proposes following the whitefly population with leaf sampling and yellow sticky traps, and releasing *E. lahorensis* and predatory entomophagous insects. If the whitefly population is very dense, he recommends spraying with a

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selective insecticide, such as a special insecticidal soap, against adults and grown larvae, and buprofezin against young larvae.

Parabemisia myricae (Kuwana) (Homoptera, Aleyrodidae)

Adult. It is 0.9-1.1 mm long, whitish, pearl-grey, light grey-blue, or light purple. Body and wings are covered with a wax powder, same as in most other adult whiteflies. The head is almost as wide as the prothorax. For morphological differences between this species and *Dialeurodes citri,* see Uygun et al. (1990).

Egg. Stalked, white, oval, narrower in its apical part, with its longitudinal axis perpendicular to the leaf surface. As embryonic development progresses, the egg becomes brownish and ultimately black.

Larva. From white to yellowish, with a flat body. The first instar can move about. After selecting a suitable site, it inserts its rostrum in the plant tissues, its antennae and legs become atrophied, and it remains there fixed for the rest of its preimaginal life.

Host plants. This whitefly is polyphagous, infesting plants belonging to 14 families. Uygun et al. (1990) mention more than 26 species of host plants in Turkey alone. Among them are citrus, avocado, pear, apple, quince, peach, pomegranate, fig, mulberry, persimmon, grapevine, rose, laurel and myrtle.

Life history and damage. This species reproduces parthenogenetically, and males are rare. In Turkey it completes 7-8 generations per year (Uygun et al. 1990). In western Crete Alexandrakis (1992a) estimates the number of generations to 9-11. In Turkey it overwinters as a larva or pupa, but under relatively warm winter weather certain individuals become adults and oviposit in winter. The same was observed in Crete (Alexandrakis 1992a). In the Peloponnese, southern Greece, where it was first observed in 1988, it overwintered as a 3rd and 4th instar larva (Michalopoulos 1989). The adults of the generation that overwintered appear from late February to early March and oviposit mainly on the very young, still developing leaves (Fig. 220). When the population is dense, they oviposit also on fully developed but not mature leaves, or even on tender young shoots and small young fruits. The eggs are laid singly or in groups on circular or semicircular lines (Uygun et al. 1990). The neonate larvae settle preferably on the underside of leaves. Larvae and adults

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suck the sap and other contents of leaves and tender shoots. The abundant honeydew they excrete allows the development of sooty mold fungi which, in addition to the reduction of the photosynthetic capacity of the trees, adversely affect the appearance, and lower the commercial value of the fruits (Fig. 221). Under exceptional cases, even leaf drop may occur. From spring to autumn there is overlapping between generations. Dense populations (Fig. 219) are produced mainly during the two periods of the year (spring and autumn) that


219


220


221

Figs. 219-221. *Parabemisia myricae.* 219.Adults on tangerine tree. 220. Preimaginal stages and abundant exuvia of them. 221.Sooty mold on an orange, because of the honeydew excreted by the insect, which dropped from the leaves to the fruit (photo B.I.K.).

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new vegetation grows on the trees, because tender plant growth is the suitable substrate for oviposition and feeding of this whitefly. *P. myricae* usually dominates or even pushes out *D. citri,* where these two species of whitefly co-exist. In certain Mediterranean countries *P. myricae* has caused serious damage to citrus and avocado. In Greece it caused considerable damage in certain areas during the first years after its entering the country. Yet, in recent years damage has not been important. The same has been the case with the woolly whitefly *Aleurothrixus floccosus.*

Control. Control with insecticides of wide spectrum of activity, i.e. non-selective, is not satisfactory as a rule. Because damage is heavier in late summer and in autumn, Michalopoulos (1991) suggests to observe the trees every two weeks during the July-October period and to spray only those trees that have considerable new tender growth, therefore those favoring the development of dense populations of the insect. He recommends buprofezin as a suitable insecticide, which inhibits ecdysis. In Turkey, very good results were obtained with mass producing and releasing the parasitic hymenopteron *Eretmocerus deBachi,* imported from California (Uygun et al. 1990). Control of this whitefly in Greece, when needed, should be in this direction (releasing the parasitic hymenopteron), in combination with cultural practices that limit excessive and prolonged new growth. When necessary, sprays with selective insecticides such as buprofezin, against first and second instar larvae, and insecticidal soaps against larvae of later instars and adults could be applied. However, such sprays should not be done frequently, and be limited to small acreages. In Italy, *P. myricae* is controlled mostly by a complex of introduced natural enemies (Zappala 2010).

In recent years another species of whitefly was established in citrus orchards of Turkey, *Aleyrodes minei* Iaccarino (Ulusoy et al. 1996).

Aphis spiraecola **Patch** *(Aphis citricola)* **(Homoptera, Aphididae)**, comm. **green citrus aphid, spiraea aphid**

Adult. The apterous parthenogenetic female is 1.2-2.2 mm long, yellow-green, green-yellow, or green (Fig. 222). The winged parthenogenetic female has the same size and color of abdomen, but has dark brown head and thorax. It much resembles *Aphis pomi* De

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Geer which, however, does not infest citrus trees (Lykouressis 1992).

Host plants. Citrus trees, and many other plants, such as species of Rosaceae, Rutaceae and Compositae.

Life history and damage. It has many generations per year. In

Figs. 222-223. *Aphis spiraecola.* 222.Larvae and a wingless adult female (Melia 1982). 223.Colony and injury to apical leaves (photo B.I.K.).

regions where it reproduces bisexually, its primary host is a species of *Spiraea.* In regions with mild winters, it is believed to reproduce continuously by parthenogenesis. It infests mainly the lower surface of young leaves and the young tender citrus shoots, from early spring on. In addition to the removal of sap, it causes curling, bending, or wavy deformation of leaves (Fig. 223). In Italy and other Mediterranean countries it is considered to be the most injurious aphid of orange, tangerine and clementine (Lykouressis 1992). It can transmit to the trees the tristeza virus, but in Florida it was reported as an inefficient vector of that virus (Knorr and Price 1958). In the Mediterranean Basin, *A. gossypii* is considered the main vector of the tristeza virus to citrus trees. Another most efficient vector of this virus is the brown citrus aphid, *Toxoptera citricida,* which has already been recorded in northern Spain, northern Portugal and Madeira, but not in Greece (Jacas et al. 2010).

Control. When necessary, an application of a suitable selective, preferably systemic, insecticide, as against other aphids, is advisable (see Aphididae).

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Toxoptera aurantii (Boyer de Fonscolombe) (Homoptera, Aphididae), comm. black citrus aphid

Adult. The apterous perthenogenetic viviparous female is 1.4-2.0 mm long, and brown or black (Fig. 224). The siphons have 1/7 to 1/8 the length of the body. Its cauda has a rounded apex and 10-26 hairs. The winged parthenogenetic viviparous female has a black head and thorax, a dark brown abdomen, and is 1.5-1.8 mm long (Fig. 225). Its cauda is black and bears 8-16 hairs. The forewings have the median vein almost always bifurcate (once), and also have a distinct dark oblong dot (pterostigma) along the front wing margin towards the apex.

Host plants. Mainly citrus, and more seldom pear, apple, species of *Rhamnus*, *Oxalis,* and certain other plants.

Figs. 224-227. *Toxoptera aurantii.* 224.Larvae and wingless adults on the undersurface of a leaf (Melia 1982). 225.Winged adult (P. Katsoyannos 1996). 226, 227.Parasitized (dead) wingless adults (photo B.I.K.).

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Life history and damage. It completes many generations per year. It overwinters as a winter egg, or as an adult female. In regions with mild winters, it is believed that it may reproduce parthenogenetically the whole year round. It infests mainly young leaves and tender shoots, and less so flowers and fruits. It causes a strong distortion of the leaves (Fig. 226). In Greece its populations are usually limited by natural enemies, especially parasitoids (Figs. 226, 227), therefore, it does not cause serious damage to this country. Its dispersion is done not only by winged individuals, but also by ants which cary apterous females even from tree to tree.

In North America this aphid has been reported to trasmit the tristeza virus of citrus trees, but in Florida it was reported as an inefficient vector of this virus (Knorr and Price 1958). In Israel too, repeated efforts to transmit the virus with this aphid have failed. In certain other countries, an effective vector of this virus is another aphid of the same genus, *Toxoptera citricida* (Kirkaldy), whose occurrence has already been verified in Spain, northen Portugal and Madeira (Jacas et al. 2010 and references therein).

Control. If absolutely necessary, a suitable selective, preferably systemic insecticide will be applied, same as against other aphids (see Aphididae).

***Aonidiella aurantii* (Maskell) (Homoptera, Diaspididae)**, comm. **citrus red scale, California red scale**

Adult. The scale (test, testa, aspidium) (for its composition see Diaspididae in the chapter of pome fruit insects) of the female is almost circular, 1.6-2.2 mm in diameter, with the larval exuvia approximately at its center. In its central part it is reddish, in its largest part orange or light brown, and in the perimeter light grey (Fig. 228). It is distinguished easily from the scale of another species of scale insect that also infests citrus, *Chrysomphalus dictyospermi* (see below), because it is never pale or dull, nor does it have a strongly prominent larval exuvium. Under the scale, the female body is oval or pear-shaped and yellow-orange. When the eggs in it develop, it becomes kidney-shaped and orange-brown. The female secretes on its ventral surface a fine membrane that separates its body from the underlying plant surface. It is viviparous. The adult male has one pair of wings, is yellow or orange, 0.6-0.8 mm long, with a wing span of 1.5

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mm (Avidov and Harpaz 1969).

Larva. The very young larva is yellow, oval, 0.2-0.25 mm long, with well developed legs and antennae. It is the stage called "crawler". The fully grown male larva has an oval scale, wider anteriorly, 0.9-1.3 x 0.6 mm, and with the scales of earlier instars off center. Under the scale its body is orange.

Host plants. It is polyphagous. In Israel it was found in species of at least 21 plant families. It is a serious enemy of citrus and certain ornamental shrubs, but also may cause serious injury to olive, fig, pear, carob, grapevine, rose, and *Evonymus* sp.

Life history and damage. In Greece, Turkey, and Italy, it completes 3 generations per year, which overlap one another. It overwinters in all larval instars (Alexandrakis 1983, 1989). In spring it becomes adult and the female, after mating, gives birth to its offspring. The larvae hatch from the eggs inside the maternal body, and soon crawl out of her scale. Viviparity in the female lasts 1-2 months in spring and autumn, and less so in summer. The neonate first-instar larvae (crawlers) disperse on the foliage and settle on leaves, shoots, twigs, branches and fruit (Figs. 228-230). The subsequent instars remain fixed at a given site, same as the adult female. This is the rule in the Diaspididae. A very hot and dry weather causes death to a considerable proportion of young larvae, even before they abandon the maternal scale. In the Chania area of western Crete, population maxima of young larvae were observed in May, July, and September-October (Alexandrakis 1989).

A. aurantii, same as the other two Diaspididae that are given below, injure citrus trees mainly by adversely affecting the appearance of the fruits, either by remaining on them (Figs. 228, 229), or by the spots they leave on the fruits after these insects have left them or are removed from the fruits. When they settle on young fruits, they cause deformations, hardening of the skin, and escharoses. When infestation is heavy, a general weakening of the tree occurs, because of loss of sap and of cell contents, and the fruits become smaller, with less juice of lower value. In recent years in the Chania area of Crete, *A. aurantii* is considered a secondary pest of citrus. Alexandrakis (1992b) attributes this to the action of natural enemies of the scale insect, which became possible with the reduction of insecticide applications against other insect enemies of citrus, and especially against the citrus mealybug *Planococcus citri.*

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Figs. 228-230. *Aonidiella aurantii* adult females and larvae: 228 on lemon, 229 on orange, 230 on sour orange leaves (photo B.I.K.).

Control. Within the frame of integrated control, and aiming at controlling *A. aurantii,* P. Katsoyannos (1996) proposes a program that includes monitoring the density and distribution of the scale's population with pheromone traps, use of yellow sticky traps, and examination of fruits and other tree parts to determine the time to intervene with biological or also chemical means. The biological means consist of releases of the parasitoid wasps *Aphytis melinus* and *Comperiella bifasciata* in spring, when the scale's population is sparce. When the population is of medium density, he recommends one or

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more sprays with buprofezin (a substance mild to the entomophagous insects), and pruning to obtain better aeration of the foliage. Later, if necessary, in those trees that have foci of the scale insect, he suggests a spray with a mixture of a summer oil and a proper organophosphorous insecticide. The same spray program is applied, if needed, also in summer against the larvae of the second generation. To be effective, the insecticide sprays should completely cover the foliage and fruits, and be done when most of the population is in the crawler stage (early first larval stadium), before the larvae form their scales. If this timing is missed, the spray can be applied even when the larvae are in the second stadium. This applies to all species of scale insects that form a protective scale (shield, aspidium). Summer oils are more selective than organophosphorous insecticides, but equally toxic to *Cales noacki* (natural enemy of *Aleurothrixus floccosus*) and dangerous to the trees if, during summer, the necessary precautions are not taken (see Tzanakakis 1995). Zapala (2010) points out that when IGRs are used, pheromone trap counts underestimate the population density of *A. aurantii*, because males of this species are more susceptible than females to these compounds. She also mentions that, at least for Italy, ant control and regular pruning to maintain foliage aeration are needed to achieve good biological control of citrus scale insects. For *Aspidiotus nerii* she suggests that mineral oils be applied before the scales move to the fruits. Wrapping sticky tape around one-year-old twigs that have old and new wood proved effective in capturing and monitoring the crawler population in Italy.

***Chrysomphalus aonidum* (L.)** (*C. ficus, Aspidiotus ficus*) **(Homoptera, Diaspididae)**, comm. **Florida red scale, citrus black scale**

Adult. In specimens found in Kalamata, Peloponnese, and described by Stathas and Kozar (2007), the scale of the adult female is black, relatively conical and its perimeter is almost circular, slightly elliptic. The larval exuvia on it are brown and situated slightly off its center. In individuals from lemon and orange the scale length was 2-2.5 mm, whereas from *Ficus benjamina* 2-2.2, and from *Ligustrum japonicum* only 1.3-1.7 mm. Under the scale, the body of the preoviposition female is slightly elliptic, becoming more circular in the ovipositing female. In all instars the adult body is lemon-yellow and in adult females from citrus in Kalamata 1.1-1.3 mm long. Ebeling (1959) gives pictures of

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adult scales with details of the pygidium (after G.F. Ferris).

Host plants. It is reported to infest plants of 279 species belonging to 69 families, and to occur in regions of all continents, and in most countries around the Mediterranean. It is considered to cause damage mostly to citrus (sources cited by Stathas and Kozar 2007).

Life history and damage. The oval lemon-yellow eggs are deposited beneath the scale. The crawlers come out and settle on leaves and fruits of any age, except very young fruits (Ebeling 1959). Only under heavy infestation was this scale insect found also on green citrus bark. In Kalamata in 2007, it infested the upper and lower leaf surface and fruits of lemon and sweet orange. In January to April its population consisted mainly of young adult females.

In Greece, although present in low population densities on certain other plants, it had not been established in citrus groves until fairly recently. The recent dense populations recorded in Kalamata, led Stathas and Kozar (2007) suspect that it may develop to a new serious citrus pest in Greece. In Cyprus, an outbreak of it in 1959 was successfully controlled by the parasitoid *Aphytis holoxanthus,* and no outbreaks occurred there until recently, when samplings on citrus and various ornamental plants in the area and within the coastal city of Limassol showed dense populations (Vassiliou 2011). All species of citrus grown there were heavily infested. Infestations of citrus, olive, jasmine, *Phoenix dactylifera, Chamaerops humilis* and various ornamentals were also recorded in the coastal area of Paphos. Vassiliou (2011) suspects that this insect is favored by the humid conditions of coastal areas of Cyprus. In the orchards of an experimental station where no insecticides were used, 90% of the pest was parasitized by *Aphitis melinus.*

In Israel and neighboring region 3 or 4 generations are completed per year plus an additional one in years with a hot summer. All kinds of citrus suffered badly from it in the forties (Schweig and Grunberg 1936). This scale insect fixes itself on citrus fruit of all ages, on leaves and young green twigs. It is known there as the black scale, and its main hosts are citrus, banana and eucalyptus, while occasional hosts are grapevine, pomegranate and *Ficus* sp. (Schweig and Grunberg 1936).

In Florida this scale insect may cause up to complete defoliation of the trees, and its presence on fruits made them unattractive to the market, as is the case also with other scale insects. In Egypt it was considered as the most important citrus pest, and is known there also

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as the black scale (Ebeling 1959). By contrast, in California it could not survive the winter in the open, thus being a pest of citrus and other plants only in greenhouses (Ebeling 1959).

Chrysomphalus dictyospermi Morgan (Homoptera, Diaspididae)

Adult. The female's scale is almost circular, 1.5-2 mm in diameter, not very convex, with the larval exuvia prominent and slightly off center. The scale is red-brown, ocher yellow or ocher brown, and sometimes almost brick-brown. Its color in uniform up to the perimeter, except the margin of the exuvium (scale) of the second-instar larva which is darker, and the exuvium of the first-instar larva which is distinctly brown or, according to some authors orange, and protrudes almost like a nipple. The adult female's scale is quite fine and semitransparent, so one can usually perceive the shape of its body. Under the scale, the body of the adult female is pear-shaped and shiny yellow before oviposition starts. Subsequently it becomes shorter and tends towards golden or ocher. There is almost no abdominal membrane (it consists of a few fine fibers). The scale of the last-instar male larva is oval, 1.0-1.4 mm long, brown to dark brown, and with the exuvium of the first-instar larva more off center than on the female scale. The scale of the male larva is not easily distinguished from that of the male larva of *Aonidiella aurantii,* whereas the scales of the adult females of the two species are easily distinguished. The adult male is winged and lemon yellow.

Host plants. It is a polyphagous species. In Morocco alone it has been observed on approximately 140 species of plants. It is an important enemy of citrus and certain species of *Ficus* and palms. Among its many hosts are the grapevine, olive, carob, acacias, eucalyptus, jasmines, *Lonicera* sp., *Ligustrum* sp., laurel and camelias.

Life history and damage. As a rule, it completes 3 generations per year, which overlap one another. It overwinters primarily as a young adult female, and secondarily as a second-instar larva. In the Campania area of southern Italy, according to Viggiani and Iannaccone (1972-73), the first ovipositing females of the overwintered generation are seen in mid-April. The first generation covers the period from mid-April to mid-July, the second from mid-July to mid-September, and the third one from mid-September to mid-April. The eggs are under

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the maternal scale. A few hours after their deposition the young larvae (crawlers) hatch and, same as in the rest of Diaspididae, disperse on the foliage and ultimately settle on sites where the female larvae will remain fixed to the end of their lives, and the male ones until they become adult. The crawlers settle mainly on leaves and fruits, less often on leafstalks and twigs, and very seldom on branches or the trunk.

On infested leaves, discoloration around the point where the mouthparts of the scale are inserted, and abnormal leaf function are caused and, under heavy infestation, leaf drop. On young fruits the injury is similar to that caused by *A. aurantii,* but deformations are less intense. In Turkey, France and Spain, this scale insect is among the main pests of citrus. In Greece, where it often co-exists with *A. aurantii,* it has not been a serious enemy of citrus in recent years, possibly because natural enemies limit its populations.

Control. With respect to insecticides, control is similar to that against *A. aurantii* (above). As to natural enemies, the wasp *Aphytis melinus* and the coccinellid *Rhyzobius lophanthae* are effective.

***Lepidosaphes beckii* (Newman)** *(L. pinnaeformis, Mytilococcus beckii)* **(Homoptera, Diaspididae)**, comm. **citrus mussel scale, citrus oblong scale**

Adult. The scale of the adult, same as that of the larvae of all instars irrespective of sex, is long and narrow. The scale of the adult female resembles the shell of a long mussel, slightly curved. It is 2.5-3.5 x 0.9-1.2 mm. It is distinctly wider in the posterior part and narrower in the anterior part where upon the larval scales remain. It resembles in shape the scale of its related species *Lepidosaphes ulmi* (Fig. 231). It is from light brown to brown-red, or dark brown-purple, lighter along the perimeter, and with the larval scales on it also lighter. Under the scale, the body of the adult female is also long and narrow, narrower anteriorly and wider at approximately the middle of the body (at the first abdominal segment). It is 1.3-1.5 x 0.7 mm, yellowish, and in the pygidium red-brown. Except for the mouthparts, the female body is separated from the plant surface by a fine whitish membrane which adheres to the plant strongly, so that it remains on the plant after the death of the insect. The male has one pair of transparent wings with purple spots, and is from white to light yellow, with black eyes and a

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total length of 1.1-1.2 mm, of which 0.3 mm is the copulatory organ.

Larva. The young first-instar larva (crawler) is light yellow, oval, and twice as long as wide, 0.35 x 0.16 mm. The scales of the subsequent larval instars are long and narrow, of approximately the shape of the adult female scale, but considerably smaller, and brown-yellow or brown-red. The scale of the grown male larva is smaller than of the female, and the larval body usually purple.

Host plants. In Greece, same as in many other countries, it infests mainly citrus and less often certain other plants.

Life history and damage. It usually has 3, but in certain areas and orchards 4 generations per year, which overlap one another. It overwinters in all stages of the life cycle, but mostly in the adult. In the Campania area of southern Italy, according to Viggiani and Iannaccone (1972-73), in January it is found as a young non-ovipositing adult female, or as an ovipositing one. In that area 4 generations per year were recorded, the first one occurring from early or mid-February to mid-April, the second from mid-April to mid-July, the third from mid-July to mid-September, and the fourth one from mid-September to mid-February. It infests mainly leaves and fruits and less so shoots and twigs. It is favored by dense foliage, shade and high humidity. This is why dense populations are not usually observed on young trees. The female lays its eggs under its body, where they remain protected until hatching of the crawlers. The crawlers abandon the maternal scale and disperse to neighboring parts of the tree. On young fruits they tend to settle at the base, under the calyx, thus not being easily detected.

Fig. 231. *Lepidosaphes beckii.* Larvae and adults on a shoot (P. Katsoyannos 1996).

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In addition to loss of sap, the presence of this scale insect lowers the commercial value of the fruits, or makes them unsuitable for export. Dense populations on the leaves cause large chlorotic spots, or early leaf drop. Considerable injury is caused mainly to grown (not young) trees with dense foliage, in densely planted orchards, and in the inner part of the canopy of the tree.

Control. Summer oils or organophosphorous insecticides are applied during the period of hatching of larvae of the generation that settles on fruits (see *Aonidiella aurantii,* above). Where selective control measures are taken against citrus insects and other pests, the populations of *L. beckii* usually are maintained within tolerable densities, mainly because of the presence of the parasitoid wasp *Aphytis lepidosaphes.*

Fig. 232. *Parlatoria ziziphi* on orange (photo B.I.K.).

Other species of the family Diaspididae that, locally or in certain years, may develop injurious populations on certain species of citrus in Greece, are *Aspidiotus nerii, Parlatoria pergandei* and *Parlatoria ziziphi* (Fig. 232). Their control with insecticides is similar to that against *Aonidiella aurantii.* Fairly recently, also *Lepidosaphes gloverii* (Packard) was found infesting orange trees in western Peloponnese (Stathas, 2003-2004).

Coccus hesperidum L. (Homoptera, Coccidae)

Adult. The parthenogenetic female body is usually oval, slightly asymetric, not very convex, 2.5-5 x 1.5-3 mm, yellow-brown or yellow, with small brown or brown-red spots and dots. It somewhat

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resembles the carapace of a turtle. The body becomes more convex the period of oviposition (Fig. 233). Males have not been observed in Mediterranean countries.

Larva. The young, first-instar larva is light yellow or yellow-red with red eyes. Its thin body is semitransparent, and in a large part appears to have the color of the substrate. Thus, it is not easily discernible from the plant surface it lies on. It much resembles the young larva of *Saissetia oleae.* The larvae of 2nd and 3rd instar are yellow-red or yellow-brown, more convex, and usually with a slight median keel along the dorsum (Fig. 233).

Fig. 233. *Coccus hesperidum.* Adults and larvae on an orange twig. Ants between them (photo B.I.K.).

Host plants. Many, belonging to at least 23 plant families (Avidov and Harpaz 1969). It is a pest of citrus. Among the many other hosts it infests are fig, mulberry, grapevine, poplars, fruit trees of the Rosaceae, acacias, laurel, cacti, begonias, ivey, *Lonicera,* oleander, carnations, and *Arbutus andrachne.* In Cyprus, a very heavy infestation of *Pistacia atlantica* has been reported (Georghiou 1977).

Life history and damage. In Greece it completes 3-4 generations per year. Many authors mention that it is oviparous, while some others that it is viviparous. This is because the eggs when coming out of the maternal body have fully developed embryons and the larvae hatch within a few hours. Therefore, it is an ovoviviparous insect that reproduces parthenogenetically. The oviposition period of each generation is long. In Morocco it lasts from 3 weeks to 2 months. This creates a great overlapping between generations. The young first-instar larvae go the the apical part of shoots and twigs and on young leaves where they settle in usually dense populations, and less often on fruits. On leaves they prefer the upper surface and the basal part of the midvein. When their

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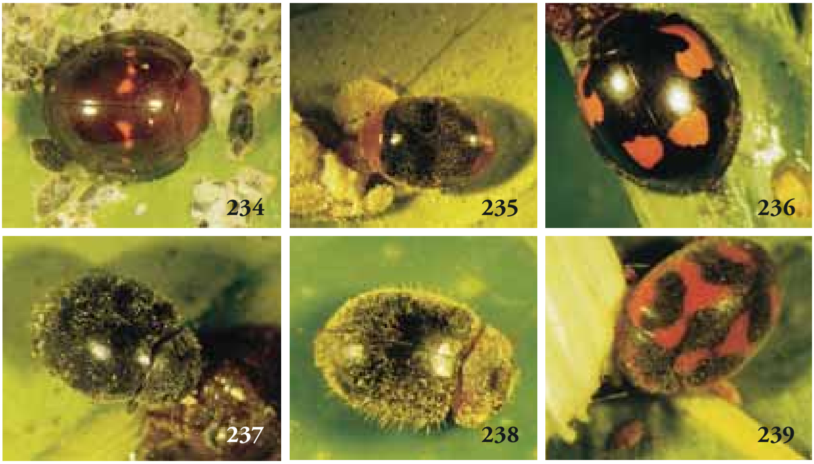
population on a tree is dense, they settle indiscriminately all over the surface of the tree, and form an almost continuous layer which covers twigs and leaves. Their density on fruits is usually lower. In addition to removing sap, this scale insect excretes abundant honeydew which soils fruits and foliage, favors the growth of sooty mold fungi, and attracts ants which protect the scale from natural enemies. In countries of the northern Mediterranean coast *C. hesperidum* has natural enemies, mainly parasitic Hymenoptera (*Coccophagus* and other), but also predatory Coleoptera (Figs. 234, 236) and Hemiptera, which limit its populations substantially, especially in summer and early autumn. This is why its populations as a rule remain sparse. Population outbreaks are usually the result of indiscriminate use of wide-spectrum insecticides.



Figs. 234-239. Predatory Coleoptera Coccinellidae, enemies of scale insects. 234.*Chilocorus bipustulatus*. 235.*Cryptolaemus montruzieri*. 236.*Exochomus quadripustulatus*. 237.*Rhyzobius forestieri*. 238.*Rhyzobius lophanthae*. 239. *Rodolia cardinalis* (P. Katsoyannos 1996).

Control. To protect the natural enemies of *C. hesperidum,* only summer oils are used against this scale in certain countries. Those oils are sprayed during the periods of emergence of the young larvae which, in many countries, approximately coincide with the periods of hatching of larvae of other species of scale insects that also infest citrus. In other countries, sprays with certain organophosphorous insecticides have also been recommended.

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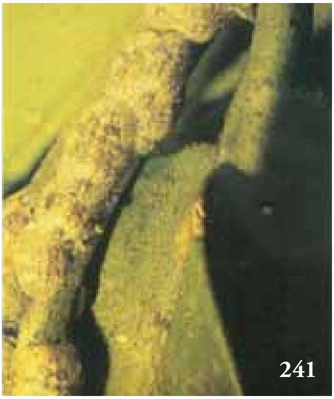
Coccus pseudomagnoliarum (Kuwana) (Homoptera, Coccidae)

Adult. On dorsal view the female is oblong and in side view slightly convex. The dorsal surface is granular, grey, with dark brown spots (Fig. 240). It is 2-7 mm long. Caution is needed, because it resembles *C. hesperidum.* For morphological differences between the two species see Ebeling (1959).

Host trees. Citrus.

Life history and damage. It completes one generation per year. It overwinters as larva and becomes adult in spring. It is considered parthenogenetic. Oviposition starts in May and lasts one to two months. The young larvae settle on the underside of leaves, where they remain and grow until autumn. From autumn to the following spring they move to twigs where they become adult (P. Katsoyannos 1996). This scale insect secretes abundant honeydew which soils foliage and fruit, and causes the development of sooty mold fungi. It has been established and constitutes a pest of citrus on the Greek island of Chios and the Dodecannese islands.



Figs. 240-241. *Coccus pseudomagnoliarum* 240.Adult female (P. Katsoyannos 1996). 241. Adults on an orange twig, enlarged three times (Essig 1926).

Fig. 242. *Ceroplastes floridensis.* Adults and larvae on a laurel leaf (photo B.I.K.).

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Control. Pruning is recommended to loosen the foliage, so as to reduce the air humidity in it. Also, avoiding excessive nitrogenous fertilization. Where necessary, organophosphorous insecticides or summer oils alone, or oils in combination with organophosphorous insecticides have been recommended during the period when most of the scale population is in the first two larval instars.

Other scale insects of the same family that infest citrus in Greece, without being considered serious pests, are *Ceroplastes floridensis* (Fig. 242), *Ceroplastes rusci* (Figs. 346-350), and *Ceroplastes sinensis.* The first two are reported also from Cyprus (Georghiou 1977). They are controlled with the same or similar measures to the above. For the black scale, *Saissetia oleae,* which in certain cases may be a serious pest of citrus, see the chapter on insects of the olive tree.

Planococcus citri **(Risso)** ***(****Pseudococcus citri)* **(Homoptera, Pseudococcidae),** comm. **citrus mealybug, grapevine mealybug**

Adult. The female is wingless, as all female scale insects are. It has an oval body, 2.5-5 x 2-3 mm, orange, yellow, pink, or greyish. The body is covered with a white wax powder (Fig. 243). Along the perimeter it has 17 or 18 pairs of short wax almost conical filaments of which the last (posterior) pair is a little longer than the rest. It moves until oviposition begins. The male is brown-yellow, brown-red or grey-brown, with black eyes, long and hairy antennae and tranparent wings which are longer than the body. Its dimensions are 0.9-1 x 0.2-0.3 mm (Fig. 243).

Egg. Oval, yellowish, 0.33-0.35 x 0.18-0.2 mm.

Larva. The first instar is light brown, the 2nd instar darker brown, and the 3rd (last) instar resembles the adult female.

Host plants. It is a polyphagous species, and an important pest of citrus trees and grapevine. In Greece, it has infested potatoes, pumpkins, and juicy fruits in storage. In the field it also infests the roots of herbaceous plants such as tomato, potato, and members of the squash family.

Life history and damage. It completes 3-4 generations per year. It overwinters as adult, egg or larva, in protected sites on the trees. The female deposits its eggs on fruits, twigs, or under dry bark, in piles that it covers with whitish wax flakes and fibers. On citrus, in

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Figs. 243-245. *Planococcus citri.* 243.On the left two adult females. In the center an adult male (pinkish, winged) (photo N.T. Papadopoulos). 244.Colony on a sour orange. 245.Result of recent infestation of oranges (photo B.I.K.).

summer, it can lay a few hundreds of eggs. The young larvae, after wandering on the tree, settle on shaded parts, and especially in sites where their body has the maximum contact with the solid adjoining surfaces. Such sites are under the calyx of various fruits, and near points of contact of fruits with other fruits, twigs, branches or leaves. In general is prefers humid and shaded sites. Dry weather does not favor it. In addition to fruits, it infests shoots, twigs, branches and leaves. Besides weakening the trees, it may cause the drop of small fruits. On navel oranges it settles also in the navel cavity and thus lowers their commercial value. It excretes abundant honeydew which soils the fruits and favors sooty mold fungi (Figs. 244, 245). Certain species of ants carry individuals of the mealybug to the base of the tree, or to the roots of neighboring herbaceous plants. Also, to protect this mealybug which offers them abundant honeydew as food, certain species of ants ”build” on the tree protective covers above groups of mealybugs. These covers-shelters which are made of wax fibers, pieces of dead insects and plant parts, cover the mealybug colonies

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completely. There, one often finds ants licking the honeydew of the mealybugs. To facilitate their entrance into those protected sites they form around and above the calyx of fruits, those ants sometimes erode the calyx, causing loosening of the connection between pedicel and fruit, and thus may cause the fruit to drop. This fruit drop is an additional indirect injury by the mealybug. The presence of the mealybug attracts also certain Lepidoptera, the caterpillars of which may cause additional injury, especially to navel oranges (see below).

On grapevines the mealybugs overwinter in fissures of the bark, or on the roots of the vines, at a depth up to 60 cm or even more. In spring, when vegetation starts, but also in summer, they move to the tender shoots where they suck the sap. They settle also on axes and pedicels of shaded grapes. The direct and indirect damage (soiling of the grapes by the insect's excreta and sooty mold) may be serious (see insects of grapevine).

Control. The Plant Protection Forecasting Services of the Greek Ministry of Agriculture used to recommend two sprays with 1.7% summer oil alone or with the addition of an organophosphorous insecticide. The first spray to be done when 60% or more of the larvae have hatched (end of May to early June), and the second spray approximately one month later, when hatching has ended. Experts of the European Union recommend a spray when 5-10% of fruits are infested in summer, and 15% of the fruits in autumn. Sampling to determine the percentage of fruit infestation by the mealybug begins when the young fruits reach a diameter of 2 cm, and continues every 3 weeks (Cavalloro and Prota eds. 1983).

In southern Turkey, the citrus growers apply biological control, releasing the predatory beetle *Cryprolaemus montrouzieri* (Fig. 235), which they obtain from the insectary of the Institute of Citrus Research of Antalya. Within the frame of integrated control of citrus pests, P. Katsoyannos (1996) recommends to release in spring and summer the parasitoid *Leptomastix dactylopii,* and subsequently the predatory *C. montrouzieri,* in combination with spraying the trees with buprofezin, or with a mixture of a summer oil and methidathion. The species of the entomophagous insect to be released and the kind of insecticide depend on the season and the degree of infestation of the trees by the mealybug. He also recommends pruning the heavily infested trees. In Crete, the release of entomophagous insects can substitute the second spray against the mealybug (for details see Alexandrakis 1992b).

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In Italy, pheromone traps, if placed early in May, are a useful tool for detecting the start of mealybug activity, and planning eventual releases of natural enemies. Under high mealybug population densities, chemical control should be applied (Zappala 2010).

In trees with colonies of *Planococcus citri* and other scale insects producing abundant honeydew, larvae of three species of multivoltine Lepidoptera may be observed. The one of these species is *Cryptoblabes gnidiella.* Its light brown larvae are found in the scale insect colonies, where they feed on honeydew and other organic substances occurring there. Therefore, those larvae are mainly saprophagous. However, in certain rare cases, they eat the fruit skin superficially near the pedicel, and may thus cause limited fruit drop. The second moth is *Ectomyelois ceratoniae.* It also oviposits where there are colonies of the scale insects producing honeydew. Its pink larvae enter the fruits and bore galleries, often causing the fruits to drop. In Greece, this species usually infests carob and seldom citrus trees. The third species of moth is *Ephestia vapidella.*

Pseudococcus adonidum **(L.) (Homoptera, Pseudococcidae)**

Adult. The female body is elliptic, 2.4-4 x 1.5-2 mm, yellow, with a median longitudinal brown stripe. However, it is covered with a white wax powder, and thus looks whitish. It has 17 pairs of wax filaments along the body perimeter, and resembles *Planococcus citri.* Yet, it is easily distinguished by the last (anal) pair of wax filaments which is very long, as long or longer than the female body, and by the penultimate pair which is approximately half as long as the last one. Also, the other perimetric wax filaments are distinctly finer than those of *P. citri,* and not conical. The antennae have 8 articles. It is viviparous. Before starting laying, the female secretes abundant wax filaments and forms around its body a wax cottony mass, in which it lays the young larvae (Fig. 246).

Fig. 246. *Pseudococcus adonidum.* Colony on *Nerium* (photo B.I.K.).

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Larva. It resembles in shape, color and general appearance the adult female.

Host plants. It is a polyphagous mealybug, as *P. citri* also is, and also infests citrus. In Greece it was observed also on asparagus, cacti, begonia (Pelekassis 1962a), and oleander (B.I. Katsoyannos, personal observation).

Life history and damage. It lives and infests citrus and other trees in a way similar to that of *P. citri.* In Mediterranean countries it is neither so frequent nor so injurious to citrus trees as is *P. citri.*

Control. If necessary, summer oils or suitable synthetic insecticides will be applied, same as against *P. citri.*

Another polyphagous mealybug, of world-wide distribution, injurious to various fruit trees, ornamentals and vegetables, is *Pseudococcus viburni* (Signoret). It has been reported to infest citrus, stone fruits, apple, and grapevine (Karamaouna and Copland 2000 and references therein).

Icerya purchasi **Maskell** *(Pericerya purchasi)* **(Homoptera, Margarodidae)**, comm. **cottony-cushion scale**

Adult. As a rule, this species is composed of apterous hermaphroditic individuals, and seldom also of males. The hermaphrodite is oval, wider posteriorly, and 4-6 mm long. It is dark red or red-brown, and sometimes covered by a sparse white wax powder. It has short black hairs, and black legs and antennae. On the ventral side of the hind part of its body it secretes a wax ovisac (Figs. 247, 250). This ovisac is a loose wax mass, which contains 500-1000 eggs, increases as oviposition proceedes, and reaches a final length of approximately 10 mm and a width of 2-3 mm, i.e. the width of the body. On its surface the ovisac has 14-16 longitudinal grooves (Avidov and Harpaz 1969). It is the ovisac that gives the cottony appearance on the plant parts bearing colonies of adult scales. The hermaphroditic individual can walk and move both as adult and larva. Its displacement on the tree stops when oviposition begins. Hermaphroditism in this species is functional, that is the gonad produces both oocytes and spermatocytes, and fertilization occurs within the gonad (for details in Greek see Tzanakakis 1995). Adult males (winged) have been observed only in certain countries.

Egg. Ellipsoid, slightly pink, 0.6-0.8 x 0.3 mm.

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Larva. The young, first-instar larva is reddish, elliptic, 0.6-0.7 x 0.3-0.35 mm, and with long hairs on the antennae and the abdomen (Fig. 248). The second-instar larva is brown-red, more hairy, with distinct waxy secretion on its back, and 2.2 x 1.3 mm. The third (last) instar is wider, 3 x 1.6 mm, and covered with white wax plates (Avidov and Harpaz 1969).

Host plants. It is polyphagous, infesting citrus and many other fruit, ornamental and native plants, woody and herbaceous, such as apple, rose, *Pittosporum* sp., acacias, laurel, geraniums, and strawberry. Of the fruit trees it infests mainly citrus, and of the ornamental shrubs *Pittosporum* sp.

Life history and damage. It usually completes 3 generations per year. It overwinters as adult, egg or larva. The young larvae (1st and 2nd instar) infest leaves and shoots. On leaves they usually are along the midrib or the main veins (Fig. 248). The more advanced larvae

Figs. 247-250. *Icerya purchasi*. 247.Adult with a developed ovisac on twig of *Pittosporum*. 248.Young larvae on leaf of *Pittosporum*. 249.Six pupal exuvia of *R. cardinalis* on the undersurface of *Pittosporum* leaves. 250.Adults along an orange twig. On the left (arrow) an adult *Rodolia cardinalis*. (photo B.I.K.).

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(3rd instar) abandon the leaves and infest only shoots, twigs, limbs, and even the trunk, same as the adults. Seldom is this insect found on fruits. In addition to sucking sap, this insect excretes abundant honeydew which soils the fruits and favors the development of sooty mold fungi.

Control. *Icerya purchasi* is considered to be the first and the classical example of successful biological control of an injurious insect by an imported entomophagous insect. It is controlled by releasing in the orchards the predatory beetle *Rodolia (Novius) cardinalis* (Mulsant) (Fig. 239). When *I. purchasi* entered California and became established in orange orchards of that state in the late 19th century, it became a serious pest of those trees. No effective insecticides against it were available in those days. The pertinent Californian authorities sent then the entomologist A. Koebele to Australia, which was the region of origin of *I. purchasi,* so that he could find effective natural enemies of the scale. Koebele found and sent to California the beetle *R. cardinalis.* Within a year from the release and settling of the beetle in one orchard, the scale insect was no more a pest of citrus in California. Since then, more than 50 countries, among which Greece, have imported this entomophagous beetle which has controlled successfully the scale insect. This beetle of the family Coccinellidae is monophagous, i.e. it feeds on only one species of prey. It completes 4-6 generations per year. It oviposits on the ovisac of *I. purchasi* and both its larvae and adults feed on all stages of its prey. Except by means of the above biological method, the scale insect can be controlled also with proper synthetic insecticides. They are used at any season of the year, except during the blooming period of the trees.

Heliothrips haemorrhoidalis (Bouché) (Thysanoptera, Thripidae)

Adult and larvae. The adult female has a generally black body, with the two last abdominal segments brick-red, light-colored legs, and yellowish antennae, except their 6th article which is black (Isaakides 1936a) (Fig. 252). It is a relatively large thrips, 1.25 mm long or longer. The two larval stages are whitish or yellowish, with red eyes (Fig. 251) (for details see Ebeling 1959).

Host plants. It is extermely polyphagous. It infests herbaceous and woody plants in the open and the greenhouse. Among its hosts are citrus, other fruit trees and grapevine.

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Figs. 251-252. *Heliothrips haemorrhoidalis.* 251. Larvae. 252.Adults (Ebeling 1959).

Life history and damage. It is parthenogenetic. According to Isaakides(1936a),itcompletes6generationsperyear.Heprobablyrefers to citrons *(Citrus medica)* in the Parga areaof coastal northwestern Greece. In California it completes 5-6generations on avocado and in Israel 7 on citrus, and up to 12 on greenhouse plants (Ebeling 1959). According to Anagnostopoulos (1939) it overwinters as adult on the trees and on wild herbaceous plants. The female inserts its eggs under the leaf epidermis. Larvae and adults rasp and suck the contents of superficial cells of leaves, flowers and fruits. The result is necrotic dots, escharosses, dermatoses, spotting of leaves and fruits and generally surface discoloration and other injury resulting from the death of superficial cells of plant and fruit tissues (Figs. 253-255). Citrons and lemons are infested more than the other citrus trees, and the appearance and consequently the commercial value of their fruits may be affected considerably. For control, see *Frankliniella occidentalis.* Anagnostopoulos (1939) recommended the destruction of the weeds in the orchards in February by plowing, and the spraying of the trees with an insecticide in March.

Pezothrips kellyanus **(Bagnall), (*Physothrips, Megalothrips kellyanus*) (Thysanoptera, Thripidae)**

Adult. According to Marullo (1998), the body is brown, the ocelli red, the tibiae yellow, and the forewings light brown.

Host plants. Citrus, flowers of Compositae, tomato, brassicas, camellia, jasmine, *Prunus* and other. It is original to Australia. In

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Greece it was recorded by zur Strassen (1986), and in 1987 large numbers were recorded in the Corinthos area of the Peloponnese (Marullo 1998 and references therein). Varikou et al. (2002) reported that it had recently developed to a serious pest of citrus orchards also in Crete. In Cyprus, it was first recorded in 1996, and has become one of the most serious pests of citrus there (Vassiliou 2005). In 1997-1998 heavy infestations especially of orange and lemon occurred in Sicily (Marullo 1998 and references therein).

Life history and damage. According to Marullo (1998), adults and larvae feed on citrus flowers and fruit. Their alimentation punctures on newly set fruitlets cause necroses, especially at the calyx end, discoloration, silvering, and partial malformation of developed fruits. In Crete, the scarring around the pedicel base of fruitlets caused by the feeding of this thrips, was formed when the fruitlets had a diameter of approximately 1 cm (Fig. 253). As the fruits grew, this ring-like scarring spread and other scarring marks appeared at the sites of contact between fruits (Varikou et al. 2002). According to Vassiliou (2005 and references therein) pupation occurs in the soil. Adults appear in spring and lay their eggs especially on the petals.

Figs. 253-255. 253.Scars on a sour orange infested by thrips when this fruit was small. 254, 255.Scars on sweet oranges (photo B.I.K).

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Up to 6 generations are completed per year. Populations on citrus are dense especially during the blooming period. Varikou et al. (2009) recorded the time needed from egg to adult of individuals reared on citrus leaf discs, with the addition of pollen of *Typha angustifolia* which favored high fecundity. Highest larval to adult survival was obtained at constant 25°C. They attribute the high population density of this thrips during the flowering of citrus in the Chania area of western Crete, to the prevailing favorable temperatures and to the simultaneous abundance of citrus pollen. In that area it can survive both the low winter and the hot summer temperatures. In Cyprus infestations were higher on lemon and grapefruit and lower on orange and tangerine. In Crete, the mean number of adult thrips per flower was 4 times higher on lemon than on orange, grapefruit or tangerine (Varikou 2002). According to certain authors, the injury may be serious, making the fruit unsuitable for the general market. According to others, the injury is mostly esthetic, yet infested fruits cannot be exported. In western Crete approximately 70% of oranges were found in the packing houses with the typical scarring caused by this thrips, thus being unsuitable for export (Varikou et al. 2002).

Control. Control measures should generally be similar to those against other Thysanoptera, such as against *Frankliniella occidentalis*. In Cyprus, Vassiliou (2005) found the proper time for the first insecticide spray to be 2-3 weeks after mass petal fall and closing of the calyx during fruit set, and the second spray 2 weeks later. He found chlorpyrifos, methomyl and acetamiprid quite effective against the larval population.

In Spain, another thrips, *Scirtothrips inernis* Priesner also causes extensive scarring of fruits and scarring and deformation of leaves of orange (Lacasa et al. 1996). Another species of thrips infesting citrus is *Scirtothrips citri* (Moulton). According to Tanigoshi (1991), its feeding on oranges, when they are less than 4 cm in diameter, causes stem end ring scarring of the rind. Later it moves to summer flush foliage. Leaf edges become misshapen, with two white-grey streaks extending along both sides of the midrib. Scarring of the fruit disappears when the fruit turns orange.

In Crete Varikou et al. (2002), in addition to *P. kellyanus* which was abundant in all citrus trees, found on flowers a few individuals of the following species: *Frankliniella occidentalis* Pergante, *Thrips atratus* Haliday, *T. major* Uzel, *T. meridionalis* Priesner, and *Melanthrips*

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fuscus (Sulzer) on mandarin, and *F. occidentalis, T. major* and *T. tabaci* on grapefruit. Varikou et al. (2009) add to the Thysanoptera injuring citrus in other countries, the species *Neohydatothrips burungae* (Hood), *Scirtothrips aurantii* Faure, *S. citri* (Moulton), *S. dorsalis* Hood and *Thrips tabaci* Lindeman.

Ceratitis capitata (Wiedemann) (Diptera, Tephritidae), comm. Mediterranean fruit fly, medfly

Adult. It has a characteristic nice coloration with black, brown and yellow spots on the thorax and the wings (Fig. 256). Its dimensions are 4-6 x 1.2-2 mm. According to Avidov and Harpaz (1969), the head is yellow, darker between the bases of the antennae, and with black hairs between the compound eyes. The antennae are brown-red and the compound eyes shiny. The thorax is dorsally black with light-colored spots, and ventrally yellow. The wings are 4.5 mm long each, are generally transparent, and have black, brown and yellow cross stripes and spots. When standing or walking, the adult holds its wings half open, so that their anterior margins (costae) are at an approximately right angle, and their posterior margins slightly leaning towards the substrate. The legs are yellow-red and the posterior tibiae possess hard yellow hairs. The abdomen is orange-yellow with two brown-red cross stripes and many fine dots. The female abdomen is slightly longer than wide. The protruding ovipositor is yellow-red, towards its apex brown, and 0.9-1.3 mm long. The male has on the front of the head two stalked clublike appendages.

Egg. It is smooth, white, long and narrow, banana-shaped, and 0.9-1.1 x 0.2 mm. It is introduced in the tissues of the host fruit.

Larva. As most larvae of the same family, it is acephalous, narrower in its anterior part and almost cylindrical in the posterior part of its body. It is white-yellow, and 7-9 x 1.5-2 mm long when fully grown (Fig. 258). The two posterior breathing stigmata at the end of the abdomen consist of 3 oblong slit-like openings each.

Pupa. Ellipsoid, light brown to dark brown, 4.4-4.5 x 2. 2.5 mm. usually it is found in the soil.

Host plants. It is a cosmopolitan, polyphagous fruit fly, with more than 250 species of host plants. It infests semiripe, almost ripe, or ripe fruits of many trees, shrubs or herbaceous plants, in tropical, subtropical and temperate regions. In Greece, it occurs from Crete up

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Figs. 256-259. *Ceratitis capitata.* 256.Adult female (photo N.D. Papadopoulos). 257. Female ovipositing in a fig. 258.Developed larvae inside a fig. 259.Injury to pears by larvae (photo B.I.K.).

to and including parts of northern Greece, and causes frequent and serious damage to citrus, pear, apple, peach, apricot, fig, and other fruits.

Life history and damage. It is considered to complete 3-6 overlapping generations per year in Greece, depending on the year and the area. It overwinters mainly as a larva inside infested fruits which remain on the trees or have fallen to the ground, and perhaps also as a pupa in the soil. In the Thessaloniki area, which lies in the northernmost zone of distribution of this species in Greece, and where winter temperatures are low, the fruit fly overwintered successfully as a larva inside infested apples (Papadopoulos et al. 1996). Likewise, in Attica and on Chios island it overwintered mainly as a larva inside citrus fruits (mostly oranges) on the trees (B. Katsoyannos et

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al. 1998, Zervas at al. 1995). Only in mild winters is it considered possible that a small percentage of the population overwinters as adult, in such regions as Crete (Mavrikakis et al. 1997). The adults appear in spring. They feed on liquid substances containing sugars and nitrogenous compounds, such as nectar, honeydew excreted by scale insects and, if need be, solid substances which their saliva can liquify so that they may imbibe them via their extensible proboscis. After feeding for a few days, maturing sexually and mating, the female bores with its ovipositor a hole in the epicarp, or deeper in the mesocarp, of host fruits and inserts usually 1-6 eggs (Fig. 257). The female often oviposits also in cracks or wounds of the fruit skin, or in oviposition holes made by other females of its species. The larvae, usually one near the other, develop at the expense of the ripe or almost ripe fruit. The injury continues after harvest. In addition to the erosion and necrosis of the fruit flesh (Figs. 258, 259), fungi and other microorganisms develop secondarily in the fruit and accelerate its rotting (Fig. 261). When the fruit starts to rot, other species of insects also oviposit there, such as *Lamprolonchaea* spp., *Drosophila* spp. or *Carpophilus* spp., the larvae of which aggravate the injury. The fully grown fruit fly larvae abandon the fruit and pupate in the soil, at a relatively small depth.

Behar et al. (2009) reviewed studies on microorganisms associated with the medfly, and especially their work. They found that the dominant populations within the fly's gut belong to the Enterobacteriaceae. They suggest that larvae begin their lives equipped with an "enterobacterial package" of pectinolytic and diazotrophic bacteria of maternal origin, which are transmitted together with the eggs into the fruit during oviposition. These bacteria subsequently establish and proliferate within the larvae as well as the fruit, and provide the larvae with ample carbohydrates and protein, due to pectin degradation and possibly nitrogen fixation. Behar et al. (2009) explain how this knowledge may also be of practical value through developing new biocontrol strategies against the fly.

On citrus fruits, the oviposition hole or "sting", as often called, is usually easily detected. It consists of a black or almost black dark brown dot, 1 mm in diameter. When the fruits are still green, this dot is surrounded by a chlorotic halo 10-20 mm in diameter. This chlorotic spot is not easily distinguished in ripe fruits that have a final orange or yellow color. In ripe oranges the change of color of the skin is slight, but sometimes a greenish ring is formed a few millimeters from the

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"sting", or a brown dot, when oviposition occurred many days earlier. In ripe lemons or grapefruits this dark dot is discernible in the yellow background of the fruit. More than one oviposition holes in a fruit are not rare (Fig. 260). Among citrus trees, the fly seems to prefer sour oranges to oranges. The cultivar Valencia is infested in summer (July), while the navel oranges in late autumn. The tangerines, are also susceptible, but often escape the infestation because they are suitable for oviposition later, usually in early winter, when the insect is no more active (see also B. Katsoyannos et al. 1998).

Infested fruits, after the larvae hatch, are unsuitable for consumption, therefore damage can be serious if the insect is not controlled in time. In areas where as a rule no control measures are taken, the population density of the fly and the damage it causes are greater towards the end of the warm season (August to November). The fly oviposits in whatever species of fruits are ripe at any given season, and can fly hundreds of meters to find them.

Control. It is done usually with insecticides, same as against other species of the same family that infest fruits. Usually cover sprays or bait sprays are applied, mostly with organophosphorous insecticides such as dimethoate, fenthion, and malathion. The bait sprays, when applied from the ground, cover only part of the foliage of every tree, or of every 2nd or 3rd tree, and an attractive component is added to the insecticide spray liquid. This attractive component is a liquid protein hydrolyzate, or a natural or synthetic product of degradation of some protein substance. Its attractiveness to the fly is due, to a large extent, to the release of ammonia. Such attractive liquids used in Greece are Alma Dacus, Buminal, Dacona, Daconyl, Dacus Bait, Entomela and Nulure. A standard such attractant mixture used in McPhail traps contains ammonium acetate, trimethylamine and putrescine. In orange orchards, Mavraganis et al. (2011) compared this standard formulation with another one of lower cost, based on pyrazines and amorphous nitrogen-based polymers. They found the latter equally effective, especially for female flies.

The need for and the time to spray are determined by following the Mediterranean fruit flies captured in traps of the McPhail type (various fruit fly traps) (Fig. 262), or traps of other suitable types (e.g. Jachson-type pheromone traps) (Fig. 263), which are suspended in the orchard a few weeks before the fruits become suitable for the flies to oviposit in. In Jackson traps the parapheromone trimedlure is placed, which is a very strong attractant for the males, while in the

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McPhail-type traps a liquid of hydrolyzed protein with borax (as a preservative) is placed. There are other types of traps for this insect too (B. Katsoyannos 1994, B. Katsoyannos 1996a, c, Zervas 1997). In “dry” traps with trimedlure (other than the Jackson sticky ones), such as the Nadel type, a volatile insecticide like dichlorvos is placed at the bottom, to kill the trapped flies. When no traps are used to follow the adult fly population and determine whether and when to spray, the fruits must be protected throughout the period they are susceptible to infestation by the fly. This is achieved with sprays, the number of which depends on the season, the area, and the species of tree. For orange and tangerine trees, the Greek Ministry of Agriculture used to recommend the following spray program (Anonymous 1973): 1) *Bait sprays.* The first spray should be applied 15 days before fruit maturity and repeated every 5-7 days. The spray liquid contains 2% hydrolyzed protein (as an attractant) and 0.3% dimethoate, or fenthion, or 0.5% malathion. Fences and shrubs on the perimeter of the orchard are sprayed, as well as the inner and upper part of the canopy of citrus trees, and especially twigs that do not bare fruits. 2) *Cover sprays.* The first spray to be done when fruit maturation begins, and repeated at approximately 20-day intervals if necessary, and if there is sufficient time to harvest so that no unacceptable insecticide residues remain on the marketable fruits. The whole tree foliage is sprayed with 0.03% dimethoate, fenthion, or other suitable organophosphorous insecticide. Yet, cover sprays of citrus on Chios island in 1960, resulted in substantial reduction of natural enemies of scale insects, especially of the black scale, the consequence being heavy infestations of the trees by this scale and development of sooty mold fungi (Report, Agriculture Directorate of Chios, unpublished data). Consequently, it is advisable to avoid cover sprays on citrus wherever possible.

In various regions and countries, such as Cyprus, Israel, Italy, Spain, Mexico, central America, Peru, the sterile insect mass release method was tried, in certain cases with success, sometimes alone, and sometimes in combination with insecticides (Hendrichs et al. 1983, Nitzan et al. 1993, and other authors). From 1994 to 1996 this method was tried experimentally in orange orchards of the Fodele valey of Heraklion, Crete, and the results were encouraging (Economopoulos et al. 1996 and personal communication). Experiments carried out in the Korinthia area of the Peloponnese, showed that the fly can be controlled satisfactorily with mass trapping (Zervas et al.

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Figs. 260-263. *Ceratitis capitata.* 260.Gum from oviposition sites on an orange. 261.Injury to sour orange by larvae. 262.McPhail type trap to capture adults. 263. Jackson type pheromone trap, with the parapheromone trimedlure as attractant, and adults that have been attracted (photo B.I.K.).

1997). Experiments to find substances more attractive than those currently available, especially to female flies, for use in mass trapping are underway in Greece and other countries. In a plastic McPhail-type trap, a combination of ammonium acetate, 1.4-diaminobutane (putrescine) and trimethylamine, placed in special evaporators being attractive for a month, was much more effective and selective for female flies than protein hydrolyzates such as Nulure (B. Katsoyannos and Papadopoulos 1997, and unpublished data of the same authors). In Crete, Economopoulos et al. (2007) applied post-harvest high-temperature treatment of Valencia oranges to kill eggs and larvae inside the fruits. Killing the insect inside the fruits is necessary for quarantine purposes, and Valencias, due to their relatively thin peel, are very susceptible to oviposition i.e. to infestation by the fly. A treatment with hot air at 56°C until the temperature at a depth of 1.5 cm and the center of the fruit reached 47°C and subsequently

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maintained at 47°C for 30 min, resulted in complete kill of eggs and grown larvae respectively. There were no substantial alterations of the treated fruit days after the treatment. This treatment is an important improvement over the use of the undesirable methyl bromide used in the past.

Phyllocnistis citrella **Stainton (Lepidoptera, Gracillariidae)**, comm. **citrus leaf-miner, phyllocnistis**

Adult. It has a length of 2-3 mm and a wing span of 7-8 mm. The body is from white to light brown. The forewings from whitish at their base become golden yellow towards their apex, and have brown longitudinal and cross stripes. When closed, the forewings have each at its apex a light-colored and next to it a dark, almost black spot (Fig. 264).

Egg. On dorsal view it is approximately circular, 0.3 mm in diameter.

Host plants. The citrus leaf-miner is polyphagous, but damages mainly citrus.

Life history and damage. This little moth is polycyclic. In Asian countries from where it originates, it completes 5-13 generations per year. It overwinters as pupa or adult, and continues its growth and development during the winter months. In Cyprus it completed 12 generations per year (Orphanides et al. 1999). It infests mainly the tender leaves of citrus trees. The eggs, one by one or 2-3 together, are deposited near the midvein of the upper or lower surface of young leaves. The larva enters the leaf and bores a characteristic sinuous (serpentine) gallery. Seen from the outside, the gallery looks silvery, semitransparent, with a median dark line, and the larva inside it can usually be seen easily. As the larva grows, the gallery widens and takes an irregular shape. At the end of the larval gallery is the pupation chamber, which usually causes folding of the leaf (Figs. 265, 266). Galleries can be bored even in the tender bark of young shoots, or even in young fruits. The injury caused consists of destruction of part of the infested leaf, and in case of heavy infestations, shoot development may stop. Curling of leaves is also observed (Fig. 267). Damage can be serious in young trees and especially in young grafts (Michelakis 1997). There is suspicion that this insect may spread the plant pathogenic bacterium *Xanthomonas campestris* pv. *citri,* or that it facilitates the infection of the foliage by this bacterium. This leaf-

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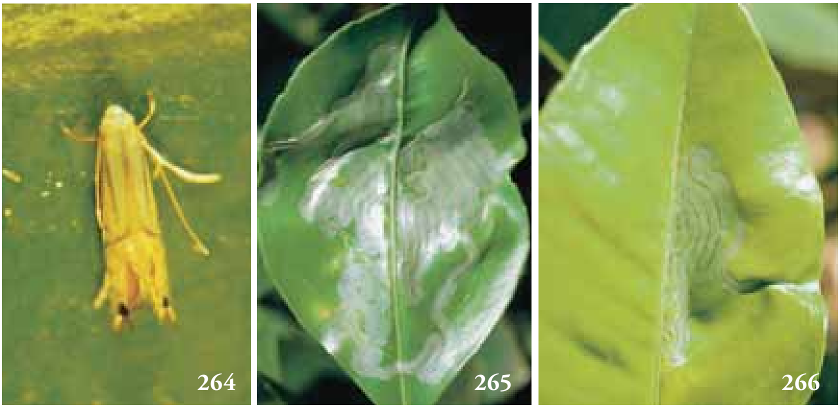

Figs. 264-267. *Phyllocnistis citrella.* 264.Adult. 265, 266, 267.Larval galleries and deformation of citrus leaves (photo B.I.K.).

miner was recorded in Greece approximately 25 years ago (Anagnou-Veroniki 1995, Michelakis 1995, 1997).

Observations in Greece seem to indicate that this moth does not develop dense populations in spring, despite the abundant tender foliage during that season. On the contrary, dense populations are observed in summer and autumn on suckers and tender foliage developing during that part of the year because of irregular irrigation (Michelakis et al. 1999, Orphanides et al. 1999, B.I. Katsoyannos personal communication). The importance of this insect as pest of citrus is not so important as had earlier been thought. In western Crete, Kalaitzaki et al. (2011) recorded denser populations of this leaf miner on orange than on mandarin.

Control. Adult population monitoring is carried out with pheromone traps. It is recommended to place these traps in the orchard in February-March, before the adults appear, and to maintain them there throughout the growing season. The proper time to apply insecticides is determined by following the number of male moths captured in the pheromone traps, and by weekly examinations of the tender growth

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for galleries in the leaves. In China, on developed trees, the tolerable population density has been set at 20% of the leaf surface, or the presence of 0.74 galleries per leaf (Ortu et al. 1995 and references therein). The insecticides acephate, dimethoate, diazinon, methomyl, phosphamidon, fenvalerate and others are considered effective (Ortu et al. 1995). Also, summer oils, fenoxycarb mainly as an ovicide, and other hormonal insecticides are recommended (Anagnou-Veroniki et al. 1995). Other experiments showed that spraying the foliage with abamectin, flufenoxuron, or imidacloprid was also effective, as was imidacloprid when smeared on the trunk or added to the irrigation water of young trees (Anagnou-Veroniki et al. 1999, Michelakis et al. 1999, Orphanides et al. 1999). It is recommended to direct the spray liquid only to the young growth of the trees, and avoid cultural measures which prolong the periods of new growth. In Italy, in adult citrus orchards, biological control combined with cultural measures (reduced irrigation and fertilization) to contain excessive new growth of the trees, have proved effective. In young and regrafted trees and in nurseries, the injury is more serious and chemicals (systemics, IGRs, mineral oils) are needed. Mineral oils have a repellent action on laying female moths (Zappala 2010).

This leaf-miner has many natural enemies, mainly parasitoid Hymenoptera, which limit its populations, at least in its countries of origin. The parasitoids *Ageniaspis citricola, Cirrospilus quadristriatus, Citrostichus phyllocnistoides, Quadrastichus* sp. and *Semielacher petiolatus* were imported from Cyprus and reared and released in Crete, to limit the populations of the leaf-miner (Kalaitzaki et al. 1999). Of the imported and established parasitoids *C. phyllocnistoides* gave the highest percentage of parasitization (Kalaitzaki et al. 2011). It is recommended that, in general, control of the leaf-miner be based on the action of parasitoids and especially on cultural measures to reduce new growth of the trees during the warm season of the year.

Prays citri **Millière (Lepidoptera, Yponomeutidae)**, comm. **lemon flower borer**

Adult. It is a small moth, 4-6 mm long, with a wing span of 10-14 mm. The body is brown-grey or grey, and the head light brown. The forewings are narrow, grey-brown and have many dark and light-colored spots of various size (Fig. 268). The hindwings are light grey or grey-brown, without spots. All four wings have dense fringes.

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Fig. 268. *Prays citri* adult (P. Katsoyannos 1996).

Egg. Slightly oval and 0.2 mm long. At first it is white or light yellow, and later as the embryo develops it becomes darker.

Larva. From whitish to greenish, with brown head and a final length of 4-6 mm.

Pupa. Brown, in a loose cocoon 5-6 mm long.

Host plants. Citrus and seldom a few other plants, such as *Achras sapota.* In Greece it infests mainly lemon and citron *(Citrus medica).*

Life history and damage. In Greece and generally in southern Europe it completes 3, and in Israel up to 4 generations per year. It overwinters probably as a larva. The adults of the generation that has overwintered (3rd) appear in April-May and oviposit on the flowers, usually on closed ones. The larva erodes the egg shell on the side it contacts the substrate, and enters directly the closed flower. It eats all parts of a flower (stamens, pistil, corolla, calyx) in which it often bores holes or galleries. It usually connects the parts of the flower, neighboring flowers, or parts of open flowers with silk threads. To complete its growth the larva eats the interior of more than two closed flowers. Also, it attacks the very small young fruits and buds, and only under exceptional cases of high population densities tender leaves and tender shoots, where it also bores galleries. It pupates usually between injured flowers, or at some other protected site on the tree. The adults of the first generation appear in August and of the second one in October-November. In the Achaia area of nothwestern Peloponnese the maximum of infestation of lemon trees occurred at approximately the end of their main flowering period. The generations that follow infest flowers and fruitlets of the following flowering periods of lemon cultivars that bear fruit more than once a year (Buchelos et al. 1963). From oviposition to adult formation 15-19 days were needed in the open, according to these authors. In 1994-1995, in a lemon orchard of eastern Peloponnese traps with a sex attractant captured adult moths throughout the year, with largest numbers from mid-May to mid-June (P. Katsoyannos et al. 1997).

In warm regions it has caused serious damage to newly budded

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young trees in autumn, attacking the scion's cambium, destroying and killing it. However, the main damage concerns the flowers and the young fruits, and is more serious and frequent on lemon and citron trees. A photograph of injury to lemon flowers and young fruits by larvae of this moth is given also by Keramidas and Passisis (1981).

Control. This moth has many natural enemies, mainly parasites, such as *Ageniaspis fuscicollis* and *Elasmus flabellatus,* which however are not always sufficiently effective. If necessary, control is effected with insecticides, or cultural measures, depending on the case. An insecticidal spray is recommended when 50% or more of flowers, or 3% or more of fruits of lemon or citron trees are infested by larvae. In Israel, the insect was controlled satisfactorily with mass trapping, using 120 pheromone traps per hectare, which were maintained in the orchard the whole year round, and the evaporator of the pheromone renewed every 2-4 months (Sternlicht et al. 1990). In Sicily, the application of formulations of *Bacillus thuringiensis* had satisfactory results. Also, control on lemon trees of a cultivar bearing fruit twice a year was achieved in Sicily with cultural measures, especially irrigation, which was timed to create an earlier blooming in spring, before the maximum of the adult population prevails in the orchard (Nucifora 1984).

Cacoecimorpha pronubana **Hübner (***C. ambustana, C. hermineana, C. insolatana, Cacoecia pronubana, Tortrix pronubana)* **(Lepidoptera, Tortricidae)**, comm. **carnation leaf roller**

Adult. According to Bovey (1966) the wingspan of the male is 15-17 mm and of the female 18-24 mm. In the male the forewings are brown or light brown with an oblique darker median stripe. This stripe is united at the tornus with an external one of similar color, so that a V is formed. The hindwings are usually orange or ochre with the perimeter of their hind side grey, brown or almost black. In the female the coloration of the wings is weaker, and only the median oblique stripe is discernible. The coloration varies with the species of the host plant. For more details in morphology see Bovey (1966), and in Greek Tzanakakis (1980).

Larva. The young larva is yellow with black head. After the first stadium the head is brown and the body has dark spots. The grown larva is 15-25 mm long. Its color varies with the food from yellow

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to olive-green (the most common), to grey-brown. The prothoracic shield is yellow or greenish, with 4 dark spots along its hind side.

Host plants. It is an extremely polyphagous species, having been observed on at least 141 species of plants, belonging to 47 different plant families. Among cultivated plants it infests carnation, chrysanthemums, jasmins, *Ligustrum* sp., laurel, *Syringa vulgaris,* olive, apple, cherry, plum, citrus, poplars, and various annual vegetables and legumes. It causes serious damage to carnation and to orange in Morocco. It occurs all around the Mediterranean.

Life history and damage. It completes 2 generations per year in England, 3 or 4 in France and Italy and 4 or 5 in Morocco. It overwinters as larva in the foliage of host plants. In southern France, the adults of the overwintered generation appear and oviposit from mid-April to end of May. The 400-700 eggs of each female are laid in 5-10 groups (plaques). In Morocco, on orange, the insect develops the whole year round, and one generation overlaps another. There on citrus, according to Delucchi and Merle (1962), there is a generation between December and February, a second one in February-April, a third one during Spring, and a fourth in June-July. A fifth generation may be observed in October-November. The larvae attack the following parts of citrus: In January-March they feed on the tender apical leaves of new shoots, which they unite with silk threads to form a shelter. Occasionally, the young larva may bore a gallery in the apical part of a tender shoot and grow as a twig borer for some time. In April-July they settle on the inside of the calyx, between two fruits touching each other, or between a fruit and a neighboring leaf, and erode the fruit superficially at its protected sites. The erosions are usually suberized, but leave undesirable scars or even deformations of the developed fruit. Erosions of ripe citrus fruit in October-November are rare. In Italy, the larva of this moth was observed attacking leaves, flowers and unripe fruits of olive (Martelli 1961).

Control. On citrus, a timely insecticidal application against the young larvae of the first generation is recommended and, if necessary, a second one later.

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Insects of the olive tree

Homoptera

- *Hysteropterum grylloides* (F.), Issidae
- *Metcalfa pruinosa* (Say), Flatidae
- *Cicada orni* L., Cicadidae
- *Lyristes plebejus* (Scopoli), Cicadidae

Psyllids

- *Euphyllura olivina* (Costa), Aphalaridae
- *Euphyllura phillyreae* Foerster, Aphalaridae
- *Euphyllura straminea* Loginova, Aphalaridae

Aleyrodoidea (whiteflies)

Aleurolobus olivinus Silvestri, Aleyrodidae
- *Siphoninus phillyreae* (Haliday), Aleyrodidae

Aphids

- *Prociphilus oleae* (Leach ex Risso), Eriosomatidae

Coccoidea (scale insects)

- *Aspidiotus nerii* (Bouché), Diaspididae
  Aspidiotus rapax Comstock, Diaspididae
- *Aonidiella aurantii* (Maskell), Diaspididae
- *Chrysomphalus dictyospermi* Morgan, Diaspididae
  Diaspis betulae Boerensprung, Diaspididae
  Dynaspidiotus britannicus (Newst.), Diaspididae
  Lepidosaphes destefanii Leonardi, Diaspididae
- *Lepidosaphes ulmi* (L.), Diaspididae
- *Leucaspis riccae* (Targioni), Diaspididae
  Parlatoria judaica Bodenheimer, Diaspididae
- *Parlatoria oleae* (Colvée), Diaspididae
  Quadraspidiotus lenticularis (Lindinger), Diaspididae
  Quadraspidiotus ostreaeformis (Curtis), Diaspididae
- *Lichtensia viburni* Signoret, Coccidae
- *Philippia follicularis* Targioni - Tozzetti, Coccidae
- *Saissetia coffeae* (Walker), Coccidae
- *Saissetia oleae* (Olivier), Coccidae
- *Pollinia pollini* (Costa), Asterolecaniidae

Hemiptera

Brachynotocoris cyprius Wagner, Miridae
- *Calocoris trivialis* Costa, Miridae
  Deraeocoris schah F., Miridae
  Rhaphigaster nebulosa Poda, Pentatomidae

Thysanoptera (thrips)

- *Frankliniella occidentalis* (Pergante), Thripidae
- *Liothrips oleae* (Costa), Phloeothripidae

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Coleoptera (beetles)

Apate monachus F., Bostrychidae
- *Sinoxylon sexdentatum* Olivier, Bostrychidae
- *Lytta vesicatoria* L., Meloidae
- *Rhynchites cribripennis* Desbrochers, Attelabidae

Steneonychus fraxini De Geer, Attelabidae
- *Otiorrhynchus* spp., Curculionidae
- *Otiorrhynchus cribricollis* (Gyllenhall), Curculionidae
- *Otiorrhynchus sulcatus* F., Curculionidae
- *Hylesinus fraxini* (Panzer), Scolytidae
- *Hylesinus oleiperda* F., Scolytidae
- *Phloeotribus scarabaeoides* (Bernard), Scolytidae

Diptera

- *Asynapta furcifer* Barnes, Cecidomyiidae
- *Dasyneura oleae* (F. Loew), Cecidomyiidae
- *Prolasioptera berlesiana* (Paoli), Cecidomyiidae
- *Resseliella oleisuga* (Targioni - Tozzetti), Cecidomyiidae
- *Bactrocera oleae* (Rossi), Tephritidae

Lepidoptera (moths)

- *Parectopa latifoliella* Millière, Gracillariidae
- *Cossus cossus* L., Cossidae
- *Zeuzera pyrina* L., Cossidae
- *Prays oleae* (Bernard) Lesne, Yponomeutidae
- *Zelleria oleastrella* Millière, Yponomeutidae
- *Lobesia botrana* (Denis and Schiffermueller), Tortricidae
- *Ectomyelois ceratoniae* (Zeller), Pyralidae
- *Euzophera bigella* Zeller, Pyralidae
- *Euzophera pinguis* Haworth, Pyralidae

Euzophera semifuneralis (Walker), Pyralidae
- *Palpita unionalis* (Hübner), Pyralidae

Cirix glauca Sc., Draepanidae
Alsophila aescularia Schiffermueller,
Hemerophila japygiaria Costa, Geometridae
- *Hybernia bajaria* Schiffermueller, Geometridae

Problepsis ocellata Friv., Geometridae
Tephroclystia pumilata Hübner, Geometridae
- *Acherontia atropos* L., Sphingidae

Hysteropterum grylloides (F.) *(H. bilobum, H. immaculatum)* (Homoptera, Issidae)

Adult. It is brownish, with light and dark spots, and 5-6.5 mm long (Isaakides 1936a) (Fig. 269).

Host plants. Olive, some other fruit trees and grapevine as hosts of

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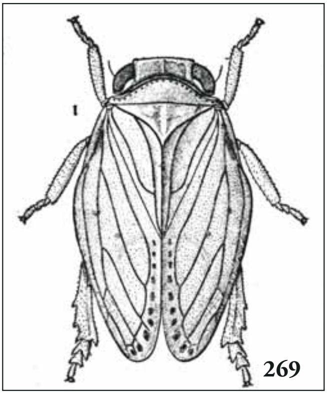
the adult, and herbaceous plants as hosts of the larvae.



Figs. 269-270. *Hysteropterum grylloides.* 269.Adult female (Silvestri 1939). 270. Groups of eggs covered by mud, on an olive twig (photo B.I.K.).

Life history and damage. It has one generation per year. It overwinters in the egg stage on the trunk, branches and twigs of olive and of certain other fruit trees and of grapevine. According to Silvestri (1934), in southern Italy, the larvae hatch usually in March-April, and come down of the trees to various herbaceous plants, on which they feed, grow, and become adults at approximately late June. The adults ascend the trees where they mate in July and early August. They lay their eggs on the bark of olive but, also of other trees, in two rows of 5-8 eggs, and cover each egg group with a kind of mud, consisting of a mixture of soil and a glandular secretion. These egg masses have a characteristic shape, approximately of a triangular prism. When the insect is abundant, large parts of branches are covered by this light brown dry mud (Fig. 270). Hatching of larvae occurs the following spring. Isaakides (1936a) mentions that the adults seem to suck the sap of tender parts of the olive tree, and especially of tender shoots. Anagnostopoulos (1939) mentions that, in addition to herbaceous plants, the larvae suck the sap of leaves, fruits and young shoots of olive and of other trees and may cause injury that justifies taking control measures. Certain other authors consider this insect harmless to trees.

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Cicadas (Homoptera, Cicadidae)

The European cicadas are among the largest homoptera, and quite familiar to humans because of the characteristic song of the males during warm summer periods. The head is short and wide, the compound eyes prominent and the short antennae located between the eyes. The mesothorax is well developed. The transparent forewings are longer than the hindwings and surpass the tip of the abdomen. The coxae of the prothoracic legs are as long as the femora which are toothed. On each side of the male abdomen there is a sound-producing organ. Using their rostrum the adults pierce and suck the sap of host plants.

The females, insert their eggs in the shoots of herbaceous plants and of trees, especially old trees. The larvae somewhat resemble the adults, and are root-feeders. Upon hatching they descend the host plant, enter the soil, and feed by piercing and sucking the sap of roots. Upon completion of their preimaginal life, usually in late spring, they come out of the soil at night and climb on the trunks of trees, poles or other surfaces where they cast the last larval skin and emerge as adults. Larval skins often remain on the trunks for some time, because of the spines on the larval legs (Isaakides 1936a).

Cicada orni L. *(Tettigia orni)* (Homoptera: Cicadidae), comm. cicada

A study of populations of the genus *Cicada* in several parts of Greece has revealed the presence of two sibling species: *C. orni* and *C. mordoganensis*. They differ in the acoustic signals produced by males during courtship and pair formation. *C. orni* is the most common species of cicada in continental Greece and some western Aegean islands, while in some other Aegean islands such as Samos, the typical *C. mordoganensis* is common instead (Simoes et al. 2002).

Adult. According to Issakides (1936a) it is 40 mm long, wings included, brown with black spots, covered with a silvery felt. According to Silvestri (1939), it is 23-35 mm long without the wings, 38-40 mm with the wings, and 10 mm wide. The body is pale brown with black spots, especially on the head, the mesonotum and the anterior part of the urotergites. It possesses a silvery pubescence. The wings are transparent, with brown costa and veins, and with two transverse series of small dark points in the middle. According to Isaakides

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(1936a), the prothorax is short and the mesothorax much developed, same as in all species of the family. The forewings are much longer than the abdomen, and also longer than the hindwings. The anterior femora are toothed on their ventral side, and there is one sound-producing organ on each side of the abdomen of males. The female abdomen ends in an ovipositor able to pierce tissues of certain plants. This relatively large homopteran, is well known to the average person, from the male's strong song, quite common during the warm hours of summer days.

Host plants. Various herbaceous and woody plants, the roots of which are fed upon by the larvae. The adults pierce and suck the sap of various species of trees, such as olive, elm, plane, and many fruit, ornamental and forest trees of the palaearctic region.

Life history. It overwinters as larva in the soil. The fully grown larvae come out in late spring and climb on tree trunks, stems of herbaceous plants, poles and other hard surfaces, where they remain motionless until their exoskeleton slits and the adult emerges. Their characteristic exuvia may stay crotched for days on the trunks. The adults suck the sap of trees. Egg laying occurs in July (Isaakides 1936a), the female cutting with its ovipositor vertical slits in the stems of such herbaceous plants as *Ampelodesma mauritanica* and *Asphodelus ramosus.* The eggs are inserted in approximately 30 groups along the axis of the stem, each oviposition slit containing 4 or 5 eggs. The larvae hatch the second half of September. They walk down to the soil, where they settle and feed on the sap of roots of various plants. It is not known whether they complete their growth in one or more years. The sucking of tree sap by the adults is not considered to cause substantial injury to the trees. Also, the loss of sap from the roots due to larval feeding has not been proven to weaken the plants or otherwise harm them to a measurable extent. Consequently, this cicada, same as the next one, are not considered harmful to olive or to other trees (Isaakides 1936a, Silvestri 1939). Among its natural enemies are birds, some reptiles and mammals consuming the adults, and Hymenoptera destroying the eggs (Isaakides 1936a).

Tibicina plebeja **Scopoli** (*Lyristes plebejus*) **(Homoptera, Cicadidae)**, comm. **cicada**

A study of the distribution of this species in Greece showed that

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it occurs on the Ionian islands, parts of the Greek mainland, and in the east on some islands of the Aegean Sea, such as Chios, Lesbos, Kos, Rhodes, Ikaria and Samos. Examination of the male genitalia showed no species other than *L. plebejus* in continental Greece and the islands. Yet, the acoustic signals (calling songs) of specimens from the islands of Chios and Rhodes were found quite different from those of specimens from continental Greece (Tsakalou et al. 2002). The scientists that carried out this study concluded that the specimens from Chios and Rhodes either belong to one of two new species of *Lyristes* recently identified in neighboring Turkey, or that Greek populations of *L. plebejus* show a variation of sound characteristics from east to west.

Adult. According to Silvestri (1939) the body is wider than in the previous species, generally black, covered with white felt. The posterior part of the pronotum and mesonotum, as well as the anterior margins of the 6th to 8th urotergites and urosternites are red-orange. A large part of the tibiae and of the costal margin of the wing veins are brown. According to Tsakalou et al. (2002) it is black, with parts orange, covered with white hairs. It is the largest of European cicadas.

Life history. It is widely distributed in the southern palaearctic region. In Italy the adults are common from late July to September, the males singing on various trees. The general life history is similar to *Cicada orni,* as are the time and way of oviposition. In addition to *Ampelodesma,* eggs are laid on *Arundo plinii, A. donax* and in vineyards (Silvestri 1939). According to Isaakides (1936a) each oviposition slit is 1 cm long and contains 6-10 eggs.

The olive psyllas

Three species of psyllas of the genus *Euphyllura* infest olive in Mediterranean countries: *E. olivina, E. phillyreae* and *E. straminea.* For years, most authors considered *E. olivina* as the most common olive psylla in Greece, therefore, it is the only species they mention as an olive pest in this country. However, a survey in continental Greece has shown that the olive trees were infested exclusively or mostly by *E. phillyreae.* Only in two localities of the Peloponnese *E. straminea* was found, but not *E. olivina* (Lauterer et al. 1986). Burckhard (1987) also records from Greece *E. phillyreae* on *Olea* and *Phillyrea,* and *E. straminea* on *Olea,* but not *E. olivina. E. olivina* seems to be dominant

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in olive groves of Italy, of southwestern Europe and North Africa, whereas *E. phillyreae* in groves of the Balcans, Crimaea, the Black Sea cost, Caucassus and Israel. For a key to distinguish the three species, see Lauterer et al. (1986).

Euphyllura olivina **(Costa) (Homoptera, Aphalaridae)**, comm. **olive psylla**, **cottony psylla of olive**

Adult. Silvestri (1939) and subsequent authors give morphological characteristics of both adults and larvae (Fig. 271).

Larva. There are 5 larval instars. The larvae secrete white wax filaments which cover their body and give the larval colonies a

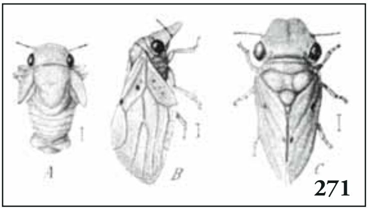

Fig. 271. Possibly *Euphyllura olivina.* Left, larva. Right, adult in side and dorsal view (Sta. Firenze, from Ribaga).

cottony appearance. They also excrete drops of honeydew (see also Arambourg and Chermiti 1986).

Host plants. Cultivated and wild olive, *Phillyrea latifolia (=media).*

Life history and damage. Assuming that the species was the dominant olive psyllid in Italy in the early part of the last century and was identified correctly (see above), its general life history and habits in that country were given by Berlese (1924, see list of references), and in more detail by Silvestri (1939). According to Silvestri it overwinters in the adult stage on the trees. Oviposition starts in early spring, and in some warmer localities even in late winter, and continues for more than a month. The eggs are inserted mostly on the inner face of young small leaves of apical buds. Silvestri (1939) concludes that in southern Italy 5 to 6 generations are completed per year. He states: "the most flourishing as a rule are the spring ones, much reduced the summer ones and little developed the autumn ones." Yet, Fimiani (1985) observed only 2 generations in 1982 on the Vivara island near Naples, with larvae from mid-April to early June, and young adults in early June and early September. Del Bene et al. (1997) recorded 3 generations in and near Florence in a year with a mild winter. The

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preimaginal stages of the spring generation covered the period from early May to late July. The adults were formed in June and July and exhibited an aestival-early autumnal diapause. Subsequently they matured and oviposited mostly in October. The larvae of the following generation covered the period from early November to mid-February, and the adults from late November to late March. In that year with a mild winter, a facultative winter-early spring third generation was observed. Until more data are collected, it is reasonable to conclude that, generally on olive in Italy, no more than 2 generations per year are completed.

In southern France, the most important “activity” of this psylla was observed at bloom, and small colonies of it during the whole growing season (Alouechdi et al.1981). In warmer regions such as the Sfax of Tunisia, Arambourg (1964) recorded 3 generations regularly, and a facultative 4th in certain years. The overwintering stages were larvae and adults of the 3rd generation, and eggs, larvae and adults of the facultative 4th one. In Lebanon and Syria, 3 to 4 generations are most likely produced according to Talhouk (1969). Of them only the spring one, which feeds on the inflorescences, is of economic interest. In Jordan Mustafa (1984) concludes that 2 generations are completed per year (for more details see Tzanakakis 2006).

When the larval colonies are on the inflorescences, which is the rule, the level of economic injury depends on the insect’s population density. In certain areas of Tunisia, under heavy infestation, losses of up to 50-60% of the yield in olives have been reported as a result of reduced fruit set. Twenty or more larvae per inflorescence can lead to such losses (Arambourg and Chermiti 1986). Furthermore, when infestations are heavy, the honeydew excreted by the larvae may favor the growth of sooty mold fungi.

Control. In case control is decided, treatment of the trees with a contact insecticide with volatile action at the beginning of blooming is recommended (P. Katsoyannos 1992a and references therein).

Euphyllura phillyreae **Foerster (Homoptera, Aphalaridae)**, comm. **olive psylla**, **cottony psylla of olive**

This species has been misidentified in the past as *Euphyllura olivina,* in Greece at least.

Adult. It resembles a small cicada, but is much smaller, only 2-3 mm

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long. The body color is green or green-brown (Fig. 272). The head is broader than long. There is much resemblance with the other two species of the same genus infesting olive in southern Europe.

Egg. Oblong, almost pear-shaped, with its basal part broader than the apical one, and with a short stalk via which the female attaches the egg to the tissues of the host plant.

Larva. There are 5 larval instars. The young (first-instar) larva is light-colored, and elliptic when seen from above. It secretes wax filaments around its body. The second- and third-instar larvae retain the light coloration, while the fourth one starts to change towards the green, and the fifth instar when fully grown is green (D.A. Prophetou-Athanasiadou, unpublished observations) (Fig. 273).

Host trees. Olive, wild olive (oleaster), *Phillyrea,* and *Osmanthus,* all Oleaceae.

Life history and damage. It has one generation per year. It overwinters as adult on the olive tree and the other host trees. In spring it matures reproductively, mates and oviposits on buds of the previous year, especially when those buds have swollen or begin to develop. It also oviposits on developing inflorescences (Prophetou-Athanasiadou and Tzanakakis 1993) (Figs. 274, 275). The larvae usually are in groups of 10-30 individuals, on the inflorescences and the young shoots, where they produce a white waxy secretion (cotton-like) which covers their body and the infested parts of the tree and is more abundant during the fifth larval stadium. Their excrement is sugary (honeydew). The waxy secretions of this species (Fig. 276) and the location of larval colonies on the tree differ from those of the aphid *Prociphilus oleae* (Fig. 277) which also infests olive and species of *Phillyrea* (see below). On olive trees of the Halkidiki and Thessaloniki areas of northern Greece oviposition occurs from late March to the 20th May, and the larvae develop mainly from mid-April to late May. Adults are formed in late May. They remain on the trees throughout summer, autumn and winter, and have mature oocytes only after mid-March (Prophetou and Tzanakakis 1977, Prophetou-Athanasiadou 1996b).

Adults and larvae suck the sap of buds, shoots, flowers and fruit. Their waxy secretion covers the inflorescences and is considered to interfere with normal bloom, fertilization and development of young fruits. However, it has not been proven that this insect affects olive production adversely, and to what extent.

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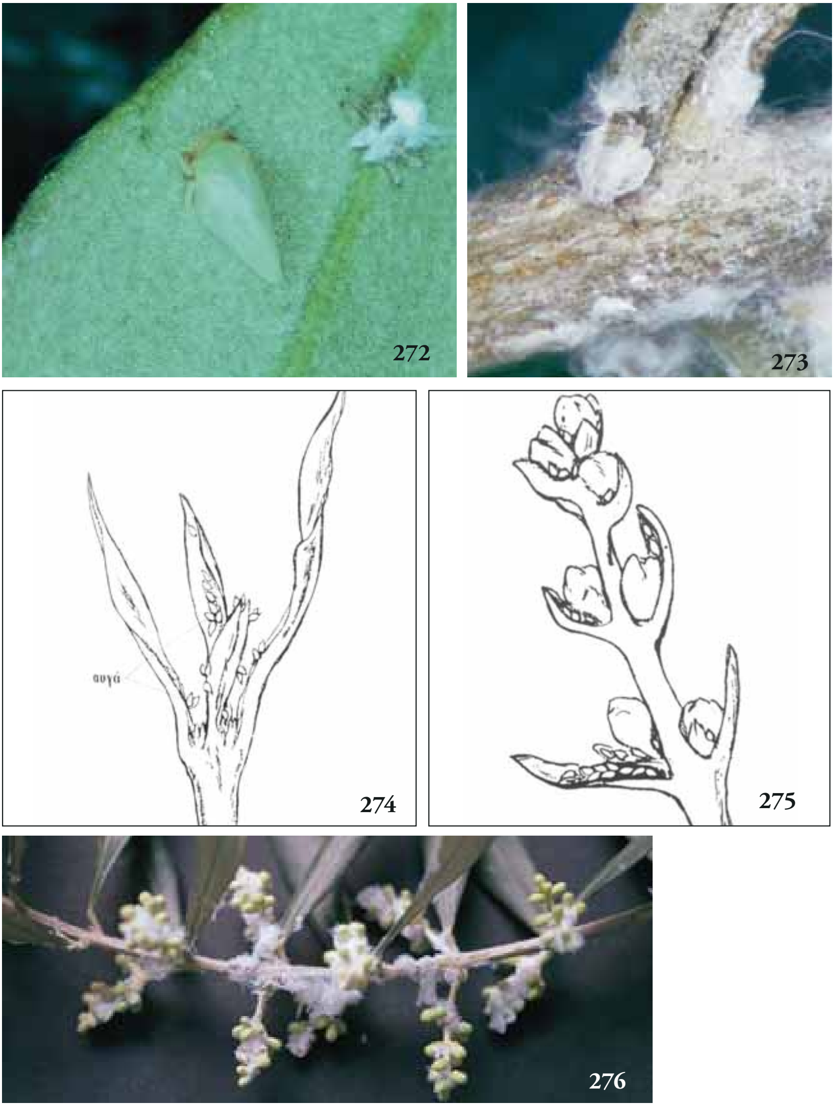

Figs. 272-276. *Euphyllura phillyreae.* 272.Adult (center), and larval exuvium (right), on the underside of an olive leaf. 273.Last-instar larva (center), and cottony wax by larvae (lower right), on the axis of an olive inflorescence (photo N.T. Papadopoulos). 274, 275.Eggs on a developing leaf bud and a developing inflorescence, respectively (D. Prophetou-Athanasiadou 1984). 276.Larvae and white waxy secretions (cottony wax) on an olive inflorescence (photo B.I.K.).

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The other two species of olive psyllas infest the tree in a similar way. The number of generations per year of *E. straminea* is not known, in Greece at least. For *E. olivina* see above.

Control. Usually no control measures are necessary against *E. phillyreae*. In the rare cases where the waxy secretions of the insect are undesirable, such as in trees in gardens or along alleys and sidewalks, the control measures against aphids can be applied. Certain authors recommend a spray with a mixture of a summer oil and an organophosphorous insecticide.

Prociphilus oleae (Leach ex Risso) (Homoptera, Pemphigidae)

Adult. Koronéos (1939) gives dimensions of antennal segments and pictures of various morphs. The fundatrigenia alata migrans has antennae with 6 segments and body length 3.5-4.1 mm. According to Roberti and Monaco (1987) the fundatrix has a brown body covered with white wax and is 3.5 mm long. For data on morphology see also Barbagallo and Stroyan (1980).

Geographic distribution. Countries bordering the northern coast of the Mediterranean.

Host trees. *P. oleae* is the only species of aphid that infests olive trees. Olive and *Phillyrea latifolia* are reported as its primary hosts (Koronéos 1939). The secondary host is not known. It is possible that it is a conifer, as are the secondary hosts of other species of *Prociphilus.*

Life history and damage. It is a bark aphid, with both adults and larvae piercing and sucking the sap of the bark of the shoots, twigs and small branches. In 1988, there was a widespread infestation of olive trees along streets of Thessaloniki. In that year, from 30 to more than 60 individuals (larvae) congregated close to one another, forming compact colonies on suckers near the base of the trunk or, more frequently, on shoots along the trunk and/or along main limbs (Fig. 277). The colonies surrounded the shoots completely or partially over a length of 2-5 cm. Most infested shoots were vigorous and vertical (Tzanakakis and Prophetou-Athanasiadou 1988).

In central and southern Greece, Koronéos (1939) found the alatae sexuparae flying to olive trees in November-December, and the fundatrix occuring in March, in crevices of the trunk of olive

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Fig. 277. *Prociphilus oleae.* Two larval colonies covered with white waxy secretions, near the base of olive water sprouts (photo. M.E.T.).

trees. Fundatrigeniae are winged and, in late April and early May migrate from the oleaceous hosts to the roots of the unknown secondary host(s). Roberti and Monaco (1987) observed in Bari (southern Italy) colonies of the insect on olive trees during the first 10 days of May. The colonies included fundatrices, alate fundatrigeniae and larvae. The alate fundatrigeniae abandoned the olive trees in mid-May. For further details regarding distribution of the colonies in the tree and periods of activity, see Roberti and Monaco (1987) and Tzanakakis and Prophetou-Athanasiadou (1988). From the limited information about the life history of this aphid, we conclude that it overwinters probably as an egg in cracks and crevices of the trunk and main limbs of olive trees or of *Phillyrea*, that the fundatrices are active in early spring, that the fundatrigeniae develop in mid- to late spring, and that subsequently they leave the olive or *Phillyrea* to probably oviposit on or near the roots of their secondary host(s). No damage to the olive tree of any kind has been reported so far. The relatively small number of colonies of the insect around shoots and twigs reported so far does not justify weakening of the tree because of loss of sap.

Aspidiotus nerii **(Bouché)** *(A. hederae* Vallot, *A. ceratoniae, A. limonii, A. oleae, A. villosus, Chermes hederae)* **(Homoptera, Diaspididae)**, comm. **ivey scale, oleander scale, white round scale**

Adult. The scale of the adult female is circular or almost so, slightly convex, 1.5-2.5 mm in diameter, light yellow or dull light brown, with

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the larval exuvium considerably darker and slightly off center. Under the scale, the female body is pear-shaped, yellow, with the pygidium darker (Fig. 278). When the eggs inside it ripen, the body of the female becomes circular and has an approximate diameter of 1.5 mm. Body size may vary also with the part of the plant infested. Thus, preoviposition females from leaves of the small-fruit olive cultivar “Koroneiki” in Crete measured 0.975 x 0.776 mm, and from fruits of the same cultivar 1.171 x 0.973 mm (Alexandrakis 1979). For further details and keys to scale insects infesting fruit trees see Bénassy (1986). The ventral hymenium (membrane) is fine and attached to the plant. The adult male is winged, of a total length of 1.1 mm (0.8 the main body and 0,3 mm the stylus), yellow or light yellow, with black eyes and yellow-brown legs and antennae. For details of the adult characters see also Silvestri (1939).

Egg. Yellow, long oval, 0.15-0.2 x 0.1 mm.

Larva. The neonate one (crawler) is yellow, long oval and 0.3 mm long. The scale of the female larva is whitish. The scale of the last larval instar of males is oval, pure white, dull, with the larval exuvium yellowish and off center. The male larvae are usually abundant and

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Figs. 278-280. *Aspidiotus nerii.* 278.Upper left part of the scale of an adult female. Lower right Adult female (yellow) without its scale (photo N.T. Papadopoulos). 279.Adults and larvae on an ivey leaf. 280.Scales and spots on a lemon (photo B.I.K.).

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form white colonies without females, or with very few females in (Fig. 279).

Host plants. It is extremely polyphagous. It infests hundreds of species of plants, belonging to over 100 plant families. It is also the most widespread armored scale insect in the world. It is found in all tropical and subtropical regions, and in greenhouses in temperate regions (Avidov and Harpaz 1969). It causes considerable damage mainly to ornamental trees and shrubs such as the oleander, but also to fruit trees such as olive, carob, and citrus, to greenhouse plants, or even to herbaceous plants such as potato. The degree of damage it causes to a given plant species varies with the area.

Life history and damage. It is multivoltine. Some authors consider it a complex of species, and some as a species with many strains, most of them bisexual, but some parthenogenetic. Of the citrus trees in Greece, *A. nerii* is harmful mainly to lemon and citron, and much less to orange and grapefruit. In Israel and Egypt it does not settle on citrus, while it damages olive (Avidov and Harpaz 1969). In western Crete, the populations of *A. nerii* infest, among other hosts, olive, carob trees and oleanders, but not citrus (Alexandrakis 1979). Attempts at artificially infesting potted orange, lemon and grapefruit trees failed there, leading Alexandrakis (1979) to hypothesize that in Crete there is a race that does not settle on citrus. The existence of different strains or subspecies justifies reports on different reproductive characteristics. For example, although it generally reproduces bisexually, there are reports of certain parthenogenetic strains in California and Russia. Ebeling (1959) mentions that this insect is viviparous, while other authors that it is oviparous. On the northern Mediterranean coast, but also as south as Crete, 3 overlapping generations seem to be the rule on olive (Alexandrakis 1979 and references therein). On lemon trees, in the Peloponnese, 3-4 generations are completed per year (Argyriou 1976), and on olive trees 3 generations on western Crete (Neuenschwander et al. 1977) as well as in coastal Halkidiki (Paloukis 1979). It overwinters mainly as an immature adult female, or as a second-instar larva. However, the other stages of the life cycle are also observed in winter, but at a much lower percentage. Percentages of each overwintering stage vary with the area and the host tree. Oviposition and hatching of larvae of the first generation occur in spring. The neonate larvae (crawlers) settle on fruits, leaves, shoots, twigs, branches or also on the trunk. In certain areas the female population density is higher on the lower

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leaf surface and the twigs and branches of the inner canopy of the tree. The crawlers of the first, second and third generation appeared on olive trees of Crete in May, July and October (Neuenschwander et al. 1977), and of Halkidiki in April, August and October respectively (Paloukis 1979). Overlapping of generations is observed on olive as well as on lemon trees (Argyriou 1976). For a brief review of the literature concerning the habits of this insect see Tzanakakis (2006).

When infestation is heavy, it is common to see fruits, leaves and twigs covered with a continuous layer of scales. In such cases the injury weakens the tree, and may even result in leaf drop and death of entire branches. Olive fruits have dark spots, deformations, do not develop normally (remain small), and do not have their normal color, nor the usual olive oil content. Damage is more important in table olive cultivars, on which the presence of the insect and the spots caused are undesirable to the buyer. Argyriou (1976) considered this scale insect the second most important enemy of table olives in central Greece, next to the olive fruit fly. On lemons, in addition to spotting (Fig. 280), it causes deformation and small fruit size (Paloukis 1979). This insect is considered susceptible to the very hot and dry weather. To adverse weather conditions and to effective natural enemies are attributed its low population densities and not serious damage in many areas. For this reason, the strategy for controlling the insect pests of olive and citrus should not annihilate the useful entomophagous insects. Among them are the predatory Coleoptera *Chilocorus bipustulatus, Exochomus quadripustulatus,* and *Rhyzobius (Lindorus) lophanthae* (Figs. 234, 236, 238), and the parasitic Hymenoptera *Aspidiotiphagus citrinus, A. lounsburyi, Aphytis coheni, A. chilensis, A. melinus* and *A. chrysomphali.*

Control. Spraying with a summer mineral oil, or an organophosphorous insecticide are recommended, at the time the neonate larvae (crawlers) of a generation appear. Paloukis (1979) recommends a spray especially against the crawlers of the first generation, and if necessary, of the second one. Of the organophosphorous insecticides preferable are those relatively mild to the above natural enemies of the scale, and especially those mild to *Aphytis chilensis, A. melinus* and *Rhyzobius lophanthae* (Bénassy 1986, P. Katsoyannos 1992a, 1996). Paloukis (1979), to allow better aeration of the foliage, recommends also thinning of the tree canopy and avoidance of excessive ferlilization and irrigation.

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Lepidosaphes ulmi (L.) (Homoptera, Diaspididae), comm. **oystershell scale**

Adult. The scale of the female is up to 3 mm long. It is long and narrow, mytiliform (mussel-shaped) or narrow pyriform, straight or slightly sigmoid, narrower in its anterior part, convex, uniformly dark brown, shiny, with the larval exuvia dark red. The color of the scale varies, mainly with the race of this armored scale insect. Under the scale, the adult female body is oblong, light-colored, with the pygidium brownish (Bénassy 1986). For details in morphology see Koronéos (1934) and Bénassy (1986).

Fig. 281. *Lepidosaphes ulmi.* Heavy infestation of pear twigs (photo B.I.K.).

Egg. White. The many eggs together are protected under the scale, behind the maternal body.

Host trees. It is a polyphagous species, living on trees of various plant families, including Oleaceae. Among its hosts are species of *Olea, Syringa, Fraxinus, Populus, Salix, Cornus, Pyrus, Prunus, Rosa, Corylus, Ulmus, Betula, Buxus,* and *Vaccinium.*

Life history and damage. It is a species with many "biological" races, which resemble one another in appearance, but differ in the way of reproduction, number of generations per year, species of host-trees, and geographic distribution. Bénassy (1986) mentions 5 such races.

In Attica (central Greece), the race that infests olive trees

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reproduces sexually and is univoltine (P. Katsoyannos 1992a, P. Katsoyannos and Stathas 1995b). It overwinters in the egg stage, under the scale of the dead mother. The larvae (crawlers) hatch in early to mid-April. Settled first-instar larvae are seen in early to late May, second instars in mid-May to early June, male pupae and the first male adults in late May to early June, the first young adult females in early to mid-June, and adult females with mature oocytes in early to mid-July. The eggs remain in diapause the remaining summer, autumn and winter, and larvae hatch in spring. On olive trees in Attica, the crawlers settle mainly on twigs, branches and trunk, more seldom on leaves, and never on fruits (P. Katsoyannos and Stathas 1995b).

When the populations of this insect are dense, they cause withering of the foliage and reduced tree growth. In Sicily, it settles also on fruits, causing spotting and deformation, thus reducing the market value of table olives (Longo 1985, from P. Katsoyannos 1992a). Natural enemies and dry climate maintain the scale's populations on olive at bearable levels. In Attica the predatory mite *Hemisarcoptes malus* (Shimer) was an effective enemy of the scale (P. Katsoyannos and Stathas 1995b).

In the Imathia prefecture of central northern Greece, Paloukis (1979) reports that *L. ulmi* infests, in order of severity of infestation: apple, pear (Fig. 281), willow, rose, olive, almond, hazelnut. In that area it completes 2 generations per year on apple. It overwinters as adult female and oviposits during winter. The eggs, 40-90, remain under the maternal scale until spring, when hatching of crawlers takes place. The various stages of the first and second generation, respectively, cover the periods: crawlers April-May and mid-July to mid-September, second-instar larvae early May to early July, and early September to early November, adult females early June to early August, and mid-October to mid-April. On apple, in Imathia, in addition to shoots and twigs which it weakens and kills, it infests fruits, reducing their commercial value. The parasitoid wasp *Aphytis mytilaspidis* is considered an effective natural enemy of *L. ulmi* in northern Greece (Paloukis 1979).

Control. If necessary, a spray is done with a contact insecticide, preferably organophosphorous, or a summer oil, when most newly-hatched larvae come out of the maternal scales and settle on the twigs and branches.

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Leucaspis riccae **Targioni** *(L. ephedrae* Marchal*)* **(Homoptera, Diaspididae)**

Adult. Bénassy (1986) gives details on the morphology of the various life stages. He points out that the size of the scale that covers the body of the adult female varies with the host plant. It is 1 mm long on olive, but up to 2.5 mm on *Ephedra.* The scale is long and very narrow, mussel-like, or long rectangular, white or silvery-white.

Host plants. Olive, oleaster, various species of *Ephedra,* such as *E. alata* (Silvestri 1939), *E. campylopoda* and *E. vulgaris* (Koronéos 1934, Lupo 1941-1945), and also *Erica arborea* and *Euphorbia* sp. (Bodenheimer 1953). In Greece and Albania Uka (1990) found it only on olive.

Life history and damage. The life history of this armored scale insect has not been studied in most countries where it occurs. It infests branches, twigs, leaves and fruit, being most abundant on leaves (Anagnostopoulos 1939). Except sucking sap, it causes deformation and spotting of fruits (Fig. 282). The young larvae settle not far from their mothers. This creates disperse, relatively dense colonies, especially on leaves and fruits. Within the general city area of Athens, from leaves he sampled for almost two years, Uka (1990) concluded that overwintering occurs mostly in the second larval instar, and in the inseminated adult female stage. The overwintering adult females had laid some of their eggs during the previous autumn, then stopped laying as the temperature dropped, and resumed laying from late May onwards. The overwintered

Fig. 282. *Leucaspis riccae.* Infestation of olive fruits and leaves.On one leaf (left) an adult black scale is seen ((photo B.I.K.).

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L2 become adults from mid-March to late April, the adult females remaining reproductively immature until early May to mid-June or even to late August. Crawlers are seen from late May to late November, with a maximum of L1 seen in September-November. Second-instar larvae of both sexes are formed in autumn and a large proportion of them overwinters, while another proportion becomes adult, mates in September, and starts laying immediately. Thus, the insect, on the basis of Uka's data in central Greece, seems to be univoltine, with the individuals that overwinter as adult females ovipositing in two periods, one in autumn and the other in the summer of the following year. Certainly further research is needed before the life history of this insect is clarified. Although in exceptional cases dense populations can be formed locally, no populations of this insect causing economic damage have been reported (Bénassy 1986). Therefore, usually no control measures are necessary.

Parlatoria oleae **(Colvée)** (*P. pergandei* Bodenheimer) **(Homoptera, Diaspididae)**, comm. **olive scale, olive parlatoria scale**

Adult. The scale of the adult female is convex, suboval or subcircular, and grey or almost white. The larval exuvia are brown, sometimes dark brown, and submarginal, towards the scale's anterior part (Fig. 283). Under the scale, the adult female body is purple, 1.5-2 x 1.2-1.6 mm, with a yellow pygidium (Fig. 284). The scale of the fully grown male larva is oblong, subrectangular, whitish, with the larval exuvium hazelnut brown, and 1.2 x 0.36 mm (Bénassy 1986) (Fig. 285). Leonardi (1907) gives the length of the male scale as 1.7 mm.

Host plants. It is an extremely polyphagous species, infesting more than 200 species belonging to 80 genera of perennial plants of various families (Huffaker et al. 1962, Kosztarab and Kozar 1988). It often infests the olive, as well as stonefruit and pome trees.

Life history and damage. In temperate climates two generations per year are completed (Silvestri 1939, Huffaker et al. 1962, Longo 1985, Bénassy 1986). This is also the case in Morocco, southern Spain, the southernmost part of Bulgaria, the Judean hills of Israel, the Middle East, various regions of the former USSR, Asia, central California, Arizona and Maryland. In certain parts of Bulgaria only one generation was observed, while in the hot interior Beit-She'an

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Valley of Israel on olives and in Iran three generations, and even four in certain areas bordering the Mediterranean (Applebaum and Rosen 1964, Bénassy 1986). In Greece, two generations per year have been reported. Most of the population overwinters as an inseminated adult female, and a smaller proportion as a second-instar larva. In the Phthiotis area of central continental Greece, on trees of the cultivar Konservolia (Amfissis), ovipositing females were recorded in April-May, crawlers of the first and second generation respectively in May-June and August-September, peaking in May and August, L1 in May-June and August-September, peaking in June and August, L2 from early June to mid-July and from mid-August to December, peaking in late June and September-October, and adult males from early June to late July, and from mid-August to mid-December, peaking in late June and from mid-September to mid-October (Argyriou and Kourmadas 1979). Limited observations in a coastal grove of the neaby island of Euboea and in a suburb of Athens showed generally the same seasonality. In the Messara valley of central Crete, crawler peaks of the first generation occurred from late April to mid-May, and of the second generation in mid-August (L.G. Tzeiranakis 2000, unpubl. report). In Macrohori Veria (north central Greece) on apple, the crawlers of the first generation were observed mainly in May and of the second one mainly in September (Paloukis 1979).

On the northern Mediterranean coast, on olive trees, the individuals destined to overwinter start reaching the adult stage in early October (Huffaker et al. 1962, Bazarov and Smelev cited by Kosztarab and Kozar 1988, Bénassy 1986). In Morocco and southern Spain, the seasonal development of the insect on olive does not differ much from that in California, as described by Huffaker et al. (1962).

P. oleae settles on leaves, twigs, branches, trunk and fruit. The proportion of each sex on each of these parts of the tree varies with the species of tree and the generation of the insect. On twigs and branches spots are formed, usually red, or even deformations. When the insect population is dense, the twigs have reduced growth and ultimately die. On fruit spots are formed, light-colored or dark (Fig. 286), and in those fruits with a thin epicarp, such as apricots, plums and olives, deformations are also caused which lower their market value, or even make them unsuitable for consumption. It is reported that olives may lose up to 20% of their content in oil (Bénassy 1986), whereas green table olives are not accepted by the canning

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Figs. 283-286. *Parlatoria oleae.* 283.Female scales on a rose shoot ((photo B.I.K.). 284.Adult female (dark purple) without its scale (photo P. Mylonas). 285.Mostly scales of male larvae on a rose leaf. 286. Scales of females and purple spots they caused to olives (photo B.I.K.).

industry. Damage to olives is caused mainly by the individuals of the 2nd generation, which settle preferably on fruit. But also on apples and other fruit, spotting caused by this insect is undesirable. In the previous few decades, damage by this scale insect in Greece was relatively limited.

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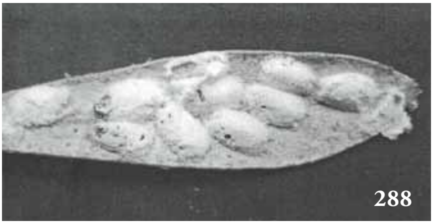
Control. In California, chemical control of the olive scale is normally not needed, because it is kept under satisfactory control with releases of two parasitoid Hymenoptera, *Aphytis paramaculicornis* (DeBach and Rosen) and *Coccophagoides utilis* (Doutt) in combination (Daane et al. 2005). This biological method is believed to be suitable also for countries of the Mediterranean Basin. As to chemical control, when necessary, the insecticides recommended against other scale insects of the same family, i.e. organic synthetic ones, mainly organophosphorous, or summer oils, can be used towards the end of the periods of hatching of crawlers.

A closely related species, *Parlatoria judaica* Bodenheimer, was recorded on olive by Bodenheimer (1953) in the Izmir area of Turkey.

Lichtensia viburni **Signoret** *(Philippia oleae, Filippia oleae)* **(Homoptera, Coccidae)**

Adult. The adult female body is elliptical, a little convex dorsally, slightly narrower in its anterior part, 2.5-4.5 mm long without the ovisac, and 3.5-6.5 mm with the ovisac. On the dorsal side it is yellow, with irregular oily-green or brownish spots. These spots are larger in the central part, and smaller towards the margin of the body. The whole body is covered with dense white wax filaments, like cotton (Figs. 287, 288). This waxy mass extends backwards to form an oval ovisac which covers the eggs. The adult female has functional legs and antennae with usually 8 articles. The adult male is winged, pale



Figs. 287-288. 287.Olive twig and leaves with adults of *Lichtensia viburni.* The white ovisacs are evident. 288. Heavily infested olive leaf (photo B.I.K.).

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orange, 1.8 x 0.5 mm, and has two wax filaments at the end of the abdomen, which are longer than its body (Silvestri 1939). Some other authors give a smaller length for the adult male.

Egg. Ellipsoid, from light yellow to yellow-orange.

Larva. The young larva has antennae with 6 articles and the grown one with 7. The female larvae undergo three ecdyses and become adult with the fourth ecdysis (according to Silvestri 1939). The female third-instar larva resembles the adult. The male second-instar larva is more oblong than the female one, and secretes on its back a characteristic white wax cover, like a scale, under which the prepupa and pupa develop. This cover is divided into 7 plates (Martelli 1905, Silvestri 1939).

Host plants. *Lichtensia viburni* is polyphagous, living on olive, other Oleaceae such as *Phillyrea* and *Jasminum,* but also on plants of several other families (for details see Quaglia and Raspi 1979a). Quaglia (1986a) considers the olive tree as the “principal” host of this insect. Pellizzari (1997) mentions as the insect’s most common host plants the cultivated olive, the oleaster, *Pistacia lentiscus* L., and the common ivy, *Hedera helix* L. There must be populations adapted to certain species of host plant. For example in Sicily, several attempts by Longo (1986) to transfer crawlers from ivy to olive failed.

Life history and damage. The insect in central Italy and in Sicily is bivoltine, and this is most probably the case on olive throughout the insect’s range. No data from other host plants are available. In Greece too, *L. viburni* completes two generations per year on olive (Isaakides 1936a). According to Quaglia and Raspi (1979a) who studied the insect’s seasonal development in Tuscany of central Italy, the first generation occurs from mid-May to early or mid-September, and the second one from early August to late June of the following year. Overwintering occurs in the second and third larval instars, on the leaves, mostly on the underside. In spring, from early March to sometime in April, the female third-instar larvae migrate from the leaves to twigs where they become adult. Male third instars remain on the leaves. The adults are seen from late April to mid- or late June, peaking in the second half of May. Those larvae that overwinter in the second instar reach the third sometime in March, then develop in the same way as those overwintered in the third instar. Quaglia and Raspi’s overwintering population had approximately equal proportions of second- and third-instar larvae. Their records suggest

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that both L2 and L3 undergo an autumnal-hibernal dormancy. The adult females remain on the twigs for 10-20 days. During this period their egg maturation proceeds. As their eggs mature from mid-May to late June, the ovigerous females migrate from the twigs to the underside of leaves. Each of them settles on the underside of a leaf, secretes a dense white cottony ovisac of wax flakes which covers the whole body, and starts egg laying. As oviposition proceeds, the female body shrinks and most of the space under the ovisac is filled with eggs. While most mature females settle on leaves, some may settle and oviposit on twigs. The average fecundity of females of either generation is reported as approximately 500 eggs (Quaglia and Raspi 1979a). The first-generation eggs are seen from mid-May to late June, crawlers from early June to early July, settled first- to third-instar larvae from mid-June to late August, adults from late July to early September, and egg-laying females as late as mid-September. The female third-instar larvae of the first generation also migrate to shoots or twigs to become adults. Adult females are formed on shoots or twigs, mate there, mature their eggs and migrate back to new leaves to oviposit. It seems that to mature her eggs the young adult female requires a different feeding substrate from that of the larvae. The crawlers settle preferably on the underside of leaves in the vicinity of the leaf they were born. The second generation eggs are seen from early August to late September or early October, crawlers from mid-August to early October, settled first instars from mid- or late August to late November, second instars from late August to late March, and third instars from mid-September to early June. A portion of second instars develops to third instars by late September and overwinter as such, while those that become second instars late, overwinter as second instars.

In Sicily, the periods of the year covered by the various stages of the life cycle are close to those in central Italy, with an earlier appearance of certain stages (for details see Longo 1986). Earlier, G. Martelli (1905, as given by Silvestri 1939) reported for southern Italy young larvae of the first generation to occur in May-June and of the second generation in August-September or even October. This is in general agreement with the above more detailed data of Quaglia and Raspi (1979a) and with the data of Longo (1986). The limited information given for Greece by Anagnostopoulos (1939) is also in general agreement with the seasonal development given above for Italy. *L. viburni* has certain similarities with *Filippia follicularis*

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(below) as to the overwintering stage, the formation of female adults on twigs, and the migration of mature adult females to leaves to oviposit.

Pellizzari (1997) states that, when populations are dense, phloem feeding can cause direct injury to leaves and twigs. Furthermore, the excretion of honeydew leads to the development of sooty mold fungi, which cause additional injury. However, population outbreaks of this insect in olive groves, such as occurred in Tuscany in the 1970s (Quaglia and Raspi 1979a), are infrequent and occur only when insecticidal applications against such major pests of olive as the olive fruit fly reduce the scale insect's effective natural enemies. Pellizzari (1997) gives lists of such natural enemies of *L. viburni* and of *Filippia follicularis*. In olive groves where integrated pest management is applied, no chemical control against *L. viburni* is needed. In Greece *L. viburni* usually does not cause serious damage to olive, because its colonies are limited to one or a few branches of the tree (P. Katsoyannos 1976), and it seems that various entomophagous insects keep its populations in check.

Control. If necessary, this insect is controlled with the insecticides used against the other scale insects infesting the olive tree, namely summer oils and organophosphorous ones. Quaglia (1986a) recommends the sprays to be done when 90% of the larvae of each generation have hatched, which according to him occurs "between June and early July" on one hand, and "from the end of September to October"on the other.

Filippia follicularis **(Targioni-Tozzetti)** *(Euphilippia olivina* Berlese) **(Homoptera, Coccidae)**

Adult. According to Berlese and Silvestri (1905), the adult unfertilized female is elliptical or oval, dorsally ochraceous, patched with brown, ventrally cream-colored, with legs and antennae ferruginous and 5.5 x 3.8 x 3 mm. Along the dorsum there is a keel of white wax, 1.2 mm in height. Sometimes this keel is not continuous or is missing. Later, after mating and when the eggs are mature, the whole body is covered by an oval, dense ovisac, 10 x 4 mm, made of white wax flakes, much resembling that of *Lichtensia viburni.* After the eggs have been laid, the female body is shrunken and covered by the anterior part of the ovisac. The adult male is winged, brownish, tending towards

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straw-color in the abdomen, and 1.6 x 0 55 mm. It has two long wax filaments at the end of its abdomen.

Larva. The crawler is sulfur yellow. The L2 is yellow, measures 1 x 0.5 mm, and has a dorsal longitudinal keel of white wax characteristic of the genus. Along the sides of the keel are curled white wax filaments. The L3 is similar to the adult female in body shape and color, but has 7 antennal segments (instead of 8) and measures 2.5 x 1.5 mm. In addition, along the dorsum it has tufts of white wax filaments, often 4, in contact with one another, to form a characteristic fluffy white crest. Quaglia and Raspi (1979b) give photographs of the various larval instars and of adults. The scale of the male larva is oval, little convex, whitish, semitransparent, with a large keel, and 3 pairs of shallow depressions. Along the keel there are numerous arched wax filaments. It measures 2 x 1.1 x 0.6 mm, including the dorsal keel. Further details and photographs of adults and larvae on olive leaves and twigs are given by Quaglia and Raspi (1979b).

Life history and damage. This soft scale insect infests leaves and twigs of the olive tree only, along the northern Mediterranean coast, and as far east as Israel. According to Quaglia and Raspi (1979b) who studied it in Tuscany, it is univoltine. It overwinters as a third-instar larva. The female larvae overwinter on the underside of olive leaves, while the male ones abandon the leaves from October to December to reach protected sites on the trunk and main limbs of the tree, where they remain until they become adults in May. After settling in those sites, the male larvae secrete wax plates, forming a white protective follicle. Under that follicle the prepupa and pupa will be formed in spring. Between January and March the third-instar overwintered larvae destined to become females migrate to the apices of twigs where they become adults in April-May and mate. Subsequently, after a period of approximately 3 weeks during which their eggs mature, the females migrate again, settle on the undersides of new leaves and start secreting the ovisac, made of white wax flakes, that completely covers the female body. Oviposition soon starts and lasts approximately one week on the average. Eggs from females of a given year are laid from late May to late June or even early July. First-instar larvae are seen from mid-June to mid-September, and second instars from mid-August to mid-October. The third instar is reached from late August to the second half of October, on the underside of leaves. Pellizzari-Scaltriti (1981), as cited by Pellizzari (1997), studied the insect further north, in the Veneto region of Italy. She

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gives approximately the same periods of occurrence of the various stages of the life cycle as Quaglia and Raspi (1979b) for Tuscany. Argyriou and Kourmadas (1977) reported that samples taken every 2 to 3 weeks over 32 months from isolated olive trees near a northern suburb of Athens, showed the insect to be bivoltine. Overwintering occurred as L2, and the periods of presence of each stage were a little earlier than those reported for the related bivoltine species *Lichtensia viburni* in Italy by Quaglia and Raspi (1979a) and Quaglia (1986a). Years later, Argyriou (1985) reported again that in an olive grove of central Greece the insect completes 2 generations per year and overwinters as L2. Yet, she also reported that in two other groves of the same area she studied the development of *Euphilippia olivina* Berlese and Silvestri, and found it univoltine, and overwintering as L2 and L3. Given the synonymy of *E. olivina* and *F. follicularis,* the identity and seasonal history of the populations occurring in central Greece should be reconsidered.

An interesting part of this insect's life history is that the male third-instar larvae migrate from leaves to their overwintering quarters in autumn to early winter, whereas the female third instars overwinter exposed on leaves, and migrate after winter proper to the apices of twigs to undergo the larval-adult metamorphosis, mate, mature their eggs, then return to leaves to oviposit.

The injury caused to the olive tree is of the same type as that caused by *Lichtensia viburni* (above), consisting of loss of plant sap and development of sooty mold fungi. Despite the insect's high fecundity of 2000 eggs (Quaglia and Raspi 1979b, Pellizzari 1997), its populations are generally not so dense as to require control measures. According to Quaglia and Raspi (1979b), it prefers to infest exposed parts of the tree. This makes pruning a sufficient measure of controlling occasional heavy infestations.

***Saissetia oleae* (Olivier)** *(Lecanium oleae, Coccus oleae)* **(Homoptera, Coccidae)**, comm. **black scale, olive black scale, Mediterranean black scale, olive lecanium**

Adult. According to P. Katsoyannos (1992a) and references therein, the adult female is ovate, highly convex, with one longitudinal and two transverse prominent keels on the dorsum, forming the letter H (Fig. 289). It is light brown when young, turning brownish-black as it matures, and measures 2.5-4 x 1.5-3 x 1.5-2.5 mm. The dorsal

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surface is more or less shiny and rugose. The antennae have 8 articles and are slightly longer than the legs. The adult male is winged but rarely encountered in north America, and not reported from Europe. Therefore, this insect probably reproduces parthenogenetically.

Egg. It is oval, 0.26-0.32 x 0.13-0.22 mm. The first few days it is white. Later it turns orange, pink, light red, or purple. The eggs of a female, approximately 2000, are located between the ventral surface of the maternal body and the surface of the plant, thus protected.

Larva. There are three larval instars, the first of which has two forms or phases: the newly hatched form or crawler, and the settled one. The crawler is oval, slightly convex on the dorsum, and 0.3-0.4 x 0.18-0.2 mm. It is ochraceous or yellowish, and has antennae with 6 articles. After wandering for a few hours or even days on the leaves or young shoots, the crawler finds a suitable site where it settles (becomes fixed). There, it introduces its mouth parts in the plant tissues and begins to suck sap and grow. In the second form, the settled L1, the body color remains approximately the same, the eyes are black, and the body becomes more oblong. The second-instar (L2) is light brown or yellowish, has antennae with also 6 articles, and measures 0.6-0.8 x 0.3-0.4 mm. On the dorsum it is more convex than the L1, has the longitudinal dorsal keel, 4 pairs of brown-purple small spots, and at the end of this second stadium appear vaguely the two transverse keels that form the H that characterizes the adult female. The L3 (last-instar) larva begins to change color and becomes slightly grey, while the brown-purple spots become larger, the keels become clearer, the antennae have 7 articles, and the body dimensions are 1-1.3 x 0.3-0.7 mm. For the morphology of the various larval instars and the life history of this insect on Corfu, Euboea, Crete and in Attica, see Argyriou (1963).

Host plants. *S. oleae* is polyphagous, living on over 150 species of trees, shrubs and herbaceous plants of various families. Among the olivaceous hosts are *Olea chrysophylla, O. europaea* and species of *Ligustrum* (P. Katsoyannos 1976, 1992a, Paparatti 1986). Leaves, shoots, twigs and small branches are infested.

Life history and damage. It is usually parthenogenetic (Pellizzari 1997 and references therein). De Lotto (1976) notes that the formation of races or subspecies may account for conflicting data on the behavior of *S. oleae.* The eggs are under the maternal body. The newly hatched crawlers disperse in search of a suitable site to settle. Most of them

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Figs. 289-292. *Saissetia oleae.* 289.Adults on a lemon shoot. 290.Sooty mold on a tangerine, from the honeydew excreted by the scale insect. 291.Infestation of olive tree and sooty mold. In the center, on the leaf, two adults of *Rhizobius forestieri.* 292. Release, from a cylindrical cage, of adults of *Rhizobius forestieri* to biologically control the black scale (photo B.I.K.).

settle along the midrib on the undersurface of leaves, in the lower part of the tree canopy. Fewer settle on terminal shoots, and only an occasional one settles on the upper surface of leaves (Pellizzari 1997, and references therein).

Univoltinism seems to be the rule in the majority of this insect's populations in most olive-growing regions of the northern Mediterranean coast (P. Katsoyannos 1992a and references therein), yet a partial second generation (involving part of the population) occurs in certain olive groves of a number of regions under specific

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conditions (see below). A number of researchers conclude that, on olive, in several but not all areas, the black scale is univoltine under dry conditions and bivoltine under humid ones, with a range of intermediate cases where there is one full generation involving the whole population, and a partial second one involving part of the population (Orphanides 1990 and references therein, Pellizzari 1997 and references therein). In a number of countries, the rate of development of the insect, especially during the growing season of plants, is affected by the condition of the tree. Near the sea coast and in irrigated olive groves, the milder weather, higher humidity and better tree condition are reported to allow faster growth of the insect in summer and early autumn, so that a portion of individuals of the main generation become adults and start ovipositing in autumn, before the onset of cold weather. The dominant overwintering stages may vary depending on the occurrence of one or of a partial second, or a full second generation. Conversely, the occurrence of a second generation may, in certain localities, depend on the overwintering stage (see below). In coastal Tuscany, Italy, most of the population overwinters as L3, a much smaller percentage as L2, and an even smaller one as reproductively immature adults (Quaglia et al. 1979, given by Paparatti 1986). According to Melis and Baccetti (1960), the females overwintering as L2 give only one generation per year which starts in June-July, while those that overwinter as adults or L3 oviposit early next year, so as to allow the development of two generations. From November through late May, the overwintering population undergoes a slow but continuous change, second instars becoming third ones, and third instars becoming adults. By June and July the L2 have disappeared, the L3 have become adults, and the adults have matured and become laying females. A similar timing of the life cycle occurs in the Huelma of Haen area of Spain (Montiel and Santaella 1995). Slow growth and gradual development to the next instar or stage during winter has been observed also on Cyprus (Orphanides 1990).

In Campania, southern Italy, preliminary results of Viggiani et al. (1973) showed the overwintering stages to be mostly L2 and L3, the relative percentages depending on the weather of the pervious year. Adults appeared mostly in April-May, and oviposited in large part from May to July, peaking in June. By late July almost all the females had laid and the population consisted mainly of neonate larvae. In autumn, L2 and L3 were formed plus a small percentage of

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young adults. Some of those adults oviposited in autumn, so that two ovipositions were observed within the same year. Tremblay (1981) reports that, in Italy, there are mixed populations within which one or two generations are completed per year in the same area. He also reports that the "torpor" phase in the neonate larva under the maternal body lasts 30-60 days. This certainly indicates dormancy in the crawler phase during summer. Tremblay (1981) further states that in regions with a hotter and drier climate, a clear summer arrest of development occurs, as a consequence of which only very few females are able to reach the adult stage before winter. Therefore, overwintering occurs mostly in the L2 and L3 instars, and in those regions only one generation is recorded constantly.

In Portugal, one or one and a partial second generation are reported, overwintering mostly as L2 and young adults (Freitas 1971). In southern France a partial second generation occurs over large areas. Extreme situations with a full second generation can arise during an exceptionally rainy summer, on trees growing in deep soil, and receiving ample irrigation during the period of normal summer drought (Panis and Marro 1985). In the Granada area of Spain, three years' records by Briales and Campos (1986) showed only one generation per year, and overwintering as L2 and L3. Young adult females were observed from April or May to June, ovipositing females mostly in June and July, oviposition between May and early September, peaking in June, L1 from June to October or November, L2 from October to May, or 2 months earlier in one of the years, and L3 from October to May or June.

On the west coast of central Greece, only one generation per year was recorded (P. Katsoyannos and Laudeho 1975). Adults were seen from mid-February to late June, crawlers in June to mid-July, fixed L1 mainly from late June to late September, and L2 and L3 from mid-August to April. In the eastern part of central Greece and on two islands, Corfu on the northwest and Euboea on the east, one generation develops away from the coast, and a partial second may develop in coastal groves, according to Argyriou (1963, 1985). On Corfu, three years' records by Stratopoulou and Kapatos (1984) show that one generation per year is the rule, including coastal localities, and only in certain years and localities a partial second generation occurred, involving a small portion of the population. Furthermore, records over a number of additional years by E. Kapatos (*in litteris)* confirm that one generation per year is the rule on that island. It

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is worth noting that Corfu is among the most humid islands of the Mediterranean, with a mean annual rainfall of 1500 mm and a high relative humidity during the growing season. On Corfu, most of the late autumn population is composed of L2 and L3, same as in western central Greece (P. Katsoyannos and Laudeho 1975). During winter, as observed also in Italy (Melis and Baccetti 1960), development goes on slowly, and in April most individuals are L3, while a smaller but considerable percentage of the population has become pre-oviposition (rubber stage) adult females. By late spring almost the whole population is composed of ovipositing females (Stratopoulou and Kapatos 1984). On Corfu, two main oviposition periods were observed, one in June-July and the other in September-October. On that island, dense populations of *S. oleae* were observed on thistles (Compositae) growing near or under olive trees (Viggiani et al. 1975). In early and mid-summer the development of preimaginal stages was slow, and the production of honeydew poor, whereas in August and early September the development of the insect was rapid and the honeydew abundant (Argyriou 1985).

On coastal northwestern Crete no distinct second generation was observed on olive (Paraskakis et al. 1980). Crawlers peaked in May-June and settled L1 in summer. L2 were observed from June to March, peaking in October, and L3 and pre-oviposition adult females most of the year, with the L3 peaking in winter, and the young adult females in spring. Black scales from Crete have been identified as belonging to the species *sensu stricto* (Tranfaglia 1977). On Crete the populations are almost exclusively confined to olive trees. Citrus and thistles are infested rarely, even when next to infested olive trees. This led Paraskakis et al. (1980) to suspect that a special race of this scale insect might occur on Crete.

On Cyprus, Orphanides (1990) found the black scale to overwinter as L1, L2, L3, and young immature adults, and to complete one generation per year, and in certain localities a partial second generation. He attributes the occurrence of a partial second generation to the weather, to cultural practices and to the physiological state of the tree. His results are in agreement with the general findings above that, on olive, in several Mediterranean areas, the insect is generally univoltine, and that a partial second generation develops in certain localities. A partial second generation was not observed by Orphanides on citrus, as was also observed by Peleg (1965) in Israel.

On the coastal plain of Israel, Peleg (1965) studied the seasonal

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development of the black scale on irrigated trees of one olive cultivar and on non-irrigated trees of two other cultivars. On the irrigated trees two generations developed per year; a summer and a winter one. All stages of the life cycle were prevalent most of the year, except in August and the first half of September, when only larvae and young adult females were present. The winter generation should be considered partial, because it did not include the whole population. On the two non-irrigated olive cultivars, only one generation developed per year. One generation was also recorded on citrus. The occurrence of a second generation on irrigated olive trees of the southern coastal plain of Israel was recorded also by Rosen et al. (1971). Peleg (1965) concludes that, in Israel, on non-irrigated olive trees and on citrus trees there is one generation per year, the seasonal history being similar to that in central California and in France. On irrigated olive trees the seasonal history is similar to that on citrus in parts of coastal California and in Italy, i.e. there is one full and a partial second generation. Blumberg et al. (1975) observed two generations per year in some citrus orchards of Israel. They attributed the observed bivoltinism to: (i) the occurrence of biologically different populations; and (ii) adaptation of the insect to changing cultural practices that improve plant nutrition, and thus may accelerate life processes in an incipient bivoltine population. Different biological races of *S. oleae* have also been reported in North America (Bartlett 1960).

On the Sais plateau in the southern part of the Fes area of Morocco, with a semiarid climate and mild winters, one and a partial second generation developed on fairly young trees of a table-olive cultivar. On those trees, the relative population density of the various larval instars differed widely between the three years of observations. In another area of Morocco, the Ouez-zane, in the northwest of the country, only one generation developed per year (Abdelkhalek 1985).

In California, *S. oleae* is reported univoltine on olive by Flanders (1942, 1970). Ebeling (1959) reports that seasonal development on olive is similar to that on citrus in the interior districts of that state. There, the insect completes one generation per year. Egg-laying occurs from April to September, with most eggs laid in May and June. In coastal areas egg-laying on citrus “may occur again in the late fall or early winter months”, so that two generations, or at least a partial second one, are observed.

The female lays a large number of eggs, fron 150 to 2500 and on the average 933 according to sources cited by Pellizzari (1997). The

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crawlers tend to colonize sites nearest to their mother. This results in high aggregation of the L1 population, which changes with time, due to mortality and migration (Pellizzari 1997 and references therein). Kapatos et al. (1997) analyzed the evolution of aggregation on heavily infested nonirrigated trees in eastern central Greece. They concluded that the spatial dynamics of *S. oleae* are characterized by patches of severe infestation, the frequency of which varies on a regional basis from year to year. The distribution of the insect in the trees was highly aggregated and the degree of aggregation changed considerably during the generation, mainly because of the action of mortality, the intensity of which is related to population density. During autumn and during spring, when the main action of natural enemies occurred, the direct density dependence of mortality reduces aggregation. The increased aggregation during winter was attributed to an inverse density-dependent relashionship between mortality and population density and also to larval movement from leaves to branches. Kapatos et al. (1997) concluded that the population dynamics of this insect in a particular area are characterized by periodic severe outbreaks usually followed by longer periods of population decline. Most authors agree that dense foliage, densely-planted groves, cool humid summers and mild winters favor the insect's population build up. Also, irrigation and nitrogen fertilizers may favor the insect by improving the nutritional value of the tree for the insect (Pellizzari 1997). Paraskakis et al. (1980) attribute the cyclic population changes of this scale insect to changes in the condition of the host plant. They consider the deterioration of the plant substrate as the prime cause of the population declines they observed on Crete. Neuenschwander and Paraskakis (1980) poin out that among the principal factors which influence the population dynamics of this insect, the condition of the host plant has been the least investigated. Kapatos and Stratopoulou (1983) describe sampling techniques for the estimation of population densities of *S. oleae.* Quayle (1916) reported on dispersal by air during summer of crawlers from infested citrus trees to other citrus trees of the same orchard. No such information is given regarding olive trees.

According to P. Katsoyannos (1992a), *S. oleae* is the most widespread and frequently encountered scale insect on Mediterranean olive trees. In addition to sap sucking, its abundant honeydew supports the development of sooty mold fungi (Figs. 290, 291). The severity of the resulting damage depends on the level of infestation. At the lowest level, before sooty mold is extensive, sap sucking has no

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obvious adverse effect on olive production. However, after the spread of sooty mold, there is reduction of photosynthesis and respiration in the leaves, which drop prematurely. In extreme cases, there may be complete defoliation of the tree and die-back of twigs. While this damage usually does not kill the tree, it can reduce the olive yield considerably. Under heavy infestations, olive production may even be annihilated for a number of years (P. Katsoyannos 1992a and references therein). Pellizzari (1997) mentions die-back of branches among the symptoms in heavily infested trees. In addition, the insect's honeydew may cause difficulty in harvesting, handling and processing of the fruit (Ebeling 1959), which is of importance in table olives cultivars.

Control. Chemical control of the black scale is difficult, because the period of hatching of crawlers lasts long. By the time the latest larvae hatch, the earliest ones have already become developed larvae (end of third stadium). Susceptible to insecticides are only the relatively young larvae, especially those of the first, and less so those of the second and early third stadium. In every insecticidal application, if the spraying is done carefully, almost all L1 will be killed, a high percentage of L2, and a much smaller percentage of L3. Therefore, for a high percentage of the larval population to be killed, hatching must have proceeded, i.e. most if not all larvae must have hatched and abandoned the maternal body. This, in many localities occurs in August. Usually an emulsion of a summer oil or an organic synthetic insecticide is used. When a summer oil emulsion is used, two sprayings are recommended: the first in July, when approximately 60% of the larvae have hatched, and the second approximately one month later, as soon as the hatching period ends. When a synthetic insecticide is used, only one spraying is usually done in August, right after the hatching of the latest larvae (P. Katsoyannos 1976). When there is a partial second generation of the insect, the effectiveness of spraying is low, because of the simultaneous presence of resistant larval instars (advanced ones) at the time of late hatching. Nevertheless, control of the black scale should as much as possible be done within the frame of integrated control of olive pests. For recommended measures, including integrated pest management, to prevent outbreaks of this insect in olive groves, see P. Katsoyannos (1992a) and references therein. For respective measures in citrus orchards see P. Katsoyannos (1996). In the Central Valley of California, pruning infested trees to facilitate air movement in summer, results in significant desiccation

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of crawlers (Daane and Caltagirone 1989).

In most Mediterranean regions, native and introduced entomophagous insects (parasitoids and predators) (Fig. 292), if not killed by certain insecticides dangerous for them, are able to keep the populations of the black scale low. This is why in certain regions olive growers prefer to spray their trees in winter. In winter the effectiveness of sprays against the black scale is lower, but the entomophagous insects are less active and thus less exposed to the insecticide (P. Katsoyannos 1992a).

In irrigated groves of the southern coastal plain of Israel, where the natural balance was upset because of repeated applications of insecticides against certain other insect pests, a second polyphagous coccid, *Saissetia coffeae* (Walker), attained pest status (Rosen et al. 1971). It completed three to four generations annually, and all life stages were present at practically all times of the year.

Pollinia pollini **(Costa) (Homoptera, Asterolecaniidae)**

Adult. The adult female (Fig. 293) is apodous, wingless (as all female coccids), strongly convex, from spherical to pyriform, 1.2-1.5 x 0.6 mm, yellow-orange to brick-red or dark brown externally and white internally. Dorsally the body is covered with a waxy protective layer, almost like a scale, measuring 1.3 x 0.7 mm. This waxy cover is grey, whitish, straw-colored, or even dark brown, and with the larval exuvia on it resembles the color of the surrounding olive bark (Fig. 293). Uka (1990) gives dimensions of pre-imaginal stages and adults of the population he studied in central Greece. The adult immature female was 1.25 x 0.96 mm, and the mature one full of eggs 1.63 mm long. In the male

Fig. 293 (275). *Pollinia pollini* on cancers and scars of cancers of an olive twig (photo B.I.K.).

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there are two larval instars, one pre-nymph, one nymph and the adult. The scale of male larvae is elliptic, with wax filaments. The adult male is winged, brown, and 1 mm long (see also Berlese and Paoli 1905).

Larva. There are three female larval instars (Silvestri 1939, Zangheri 1959, Alexandrakis 1980). Uka's crawlers were 0.43 and fixed L1 0.61 mm long. Crawlers were yellowish. Female L2 were amber yellow, oval or lemon-shaped, and 0.77 x 0.48 mm, while L3 were pale yellow.

Host trees. The olive is stated as the only host by most authors (Martelli 1959b, Zangheri 1959, Alexandrakis 1980 and references therein). Bodenheimer (1953) recorded it on both olive and oleaster in Asia Minor.

Life history and damage. From Italy and Greece the insect has been reported from semivoltine (hemicyclic) to bivoltine. Semivoltinism is reported by Zangheri (1959) around Lake Garda, in the Veronese region of northern Italy, and by Uka (1990) near Athens, central Greece. Univoltinism is reported by Kyparissoudas (1980) on Lesbos island of the eastern Aegean and by Liotta and Sammartano (1981) on Sicily. Bivoltinism is reported by A.M. Berlese (1907) in Tuscany, Silvestri (1939) citing Martelli (1908) also in Italy, and Alexandrakis (1980) on western Crete, while Damiano (1963) estimates that in the maritime parts of Tunisia more than two generations per year may be completed. For a summary of data by these authors see Tzanakakis (2006). Here we give the semivoltine seasonal development in northern Italy and central Greece, and the univoltine in some other areas.

Around Lake Garda, Italy, this scale insect overwinters in various stages, but usually as adult females, unmated or mated (Zangheri 1959). The unmated females attain maturity in late spring and in summer, and mate from mid-August to October. They pass another winter as mated females, and oviposit in late spring of the second year. The individuals that overwinter as mated adult females (this is the case in their second winter), mature their eggs by spring and oviposit in spring and summer of their second year. Male adults appear between mid-August and late October and mostly in September, and mate in that season. The first crawlers are seen in May, but hatching is prolonged for months and ends in the first half of August. It is clear from Zangheri's (1959) description that his populations were semivoltine for females and univoltine for males.

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In the area of Athens, the overwintering population consisted of unmated adult females (ca. 60-80%), mated adult females with eggs (ca. 20%), a small percentage of L2 and an even smaller of L1. The individuals that overwinter as mated adult females have mated in the previous mid- to late summer, but have not began maturing their eggs before November. In those females egg maturation proceeds slowly during winter and early spring. Oviposition starts in late April, is intense until mid-May, and continues for approximately 4 months, until August or even later, so that crawlers are seen from mid-April to mid-August, but mostly in May-June. First-instar larvae (fixed L1) start to be formed in early June. This instar lasts 20-25 days. Female L2 are formed from late June to early August, and are seen in varying percentages of the population the whole year round. Adult females are formed mostly from late July to the first 10 days of August. Of these females only a relatively low percentage (ca. 30%) mate in their first summer. These are the earliest adult females which meet the adult males of their own generation. The remaining majority either do not meet those males because of an observed 50-day protandry, or perhaps because they are not yet sexually mature to attract the males (Uka 1990). Thus, most adult females overwinter as virgin during their first winter. They gradually mature sexually until late spring, and all mate in summer, to pass their second winter as mated females, and oviposit the next spring, as above. Adult males are seen from mid-June to mid-August. They mate mostly in June and July with adult females of the previous year, and less so with females of their own generation, which have reached a mating stage. Therefore, in central Greece, there is univoltinism in males and semivoltinism in females. This semivoltine seasonal development in females and univoltine in males of central Greece, is in general agreement with that found by Zangheri (1959) in the considerably cooler region of northern Italy, and shows that detailed studies are needed to clarify the voltinism of this insect in certain other regions, where the published data are not convincing. Uka (1990) points out that in the area he worked, the reproductively immature adult females undergo an autumnal-hibernal-vernal dormancy in the first year, and the mated ones a late aestival-autumnal dormancy in the second year.

On Lesbos, univoltinism has been reported (Kyparissoudas 1980). On that island, the insect overwinters as a mated young adult female, and as a mated “pre-oviposition” adult female. The young adult females occur from mid-July to late April of the next year, adult

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males from mid-July to late October, matings are observed in August-October, and pre-ovipositon females mostly from mid-November to late May or early June. Ovipositing females occur from mid- or late April to early or mid-August, and crawlers from late April to early August.

In Sicily, where univoltinism is also reported (Liotta and Sammartano 1981), the insect overwinters as young adult female, and as “ovigerous”, i.e. pre-oviposition, adult female. Young adult females are seen from mid-June to early March or even early April, ovigerous females from late October to mid- or late June, ovipositing females from late March or early April to mid- or late August, and crawlers from late March to early September or early October. Adult males are seen from early July to early or mid-November. Thus, seasonal development on Sicily resembles that on Lesbos, with a slight earliness in the appearance of most stages. Liotta (1981) further mentions that, in some regions of Sicily, the crawlers occur mostly in two periods, April-June and September-November, thus suggesting that there may be a second annual generation, probably involving part of the population, or that the oviposition period, whether continuous or interrupted, extends beyond late August.

On western Crete the insect overwintered mostly as pre-oviposition adult female, less so as L2, and even less as L1 (Alexandrakis 1980). The proportion of ovipositing females and crawlers in winter was very low. The pre-oviposition females matured their eggs and became ovipositing females from March onwards, and oviposited from March to June or even to September. Crawlers were observed from March to June or July, peaking in April. First-instar larvae were seen mostly from April to August, with small numbers the year round. Second instars occurred mostly from June to February with smaller numbers the year round. Alexandrakis (1980) concludes that two generations are completed per year, but points out that only if we consider both the dead and the live crawlers in his samples is the second generation clearly seen. Therefore, bivoltinism on Crete needs to be verified by more experimental data.

A summary seasonal history in Greece, shows the larvae to develop the warm season of the year. The female ones complete their growth and become adult from June-July on (Crete), from July (Lesbos) and mainly from late July to the 10th August (Attica). The adult males appear from July to October (Lesbos), and from mid- to late June (Attica). In Attica, the male nymphs become adult when the females

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that have overwintered (females of the previous year) are mature for mating. In Attica matings occur in June to late July. At that time most female larvae of the year have not become adult. This is why they overwinter as immature adult females. They mature and mate the summer of the next year, and thus oviposit in the spring of their second year of life (Uka 1990).

Bivoltinism is reported from Tuscany, Italy by A.M. Berlese (1907), on the basis of two periods of hatching of crawlers. However, the periods covered by the other stages of the life cycle are not given, therefore, further work is needed before bivoltinism in Tuscany is considered a fact.

The crawlers of this ovoviviparous species, as reported from Italy, remain first under the maternal body cover, then come out and search for a site to settle. Male crawlers settle mostly on terminal young leaves and new tender shoots of the season, whereas female ones prefer twigs and branches. The female crawlers settle preferably in cracks, fissures, wounds or scars of the bark, including those caused by frost or hail (Fig. 293), at the base of axillary or even terminal buds, around openings of galleries of bark beetles, especially those of *Phloeotribus scarabaeoides,* or under the body of live or dead adults of the black scale*, Saissetia oleae,* of certain other scale insects infesting the olive tree, or even under the body of individuals of their own species. When they do not find such protected sites, female crawlers settle on axils of twigs and branches. They usually settle on shoots and twigs 3-6 mm in diameter, but sometimes on limbs or even on the trunk of young olive trees (A.M. Berlese 1907, Zangheri 1959). A portion of the female crawlers go to the new growth, while others remain around the maternal body, thus forming characteristic colonies which give the impression of tubercles (Alexandrakis 1980). The behavior of crawlers in other regions is similar to the above. On western Crete, the population density of the insect was higher on the southern part of the tree (Alexandrakis 1980), whereas in the Athens area on the southeastern part (Uka 1990).

Larvae and female adults suck the sap of the tree. Their presence at the base of buds inhibits normal development of the buds, shoots and leaves, causes early leaf drop, and ultimately lowers the yield (Zangheri 1959, Alexandrakis 1980, 1985). The sooty mold that develops on the honeydew the insect excretes adds to the damage. When infestation is high, there is general weakening of the tree, reduction of the annual growth, and fruit production may be seriously

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reduced (Alexandrakis 1995). In general the insect infests preferably weak trees, and thrives best in areas with a warm and dry climate, and in localities with insufficient soil water. In the maritime areas of Tunisia, *P. pollini* is considered the second most important insect pest of olive (Damiano 1966). Fortunately, this is not so in most other olive growing regions. Although insecticides have been used against heavy infestations by this insect, control measures should be largely cultural, aiming at strengthening the trees through proper pruning, irrigation, weed control, and fertilization.

Calocoris trivialis **Costa** *(C. limbicollis, Closterotomus trivialis)* **(Hemiptera, Miridae)**

Adult. Barbagallo (1970) gives details of the external and internal structure of the adult. The body is long and narrow (Fig. 294). The female measures 7.5-8 x 2.5-3 and the male 6.5-7.5 x 2-2.5 mm. The body color gradually darkens during the first 15-20 days as reproductive maturation proceeds. The reproductively mature female is yellowish-green ventrally. Dorsally its head is greenish-brown, with oblique blackish stripes. The pronotum is greenish, with 4 almost circular black spots (2 submedian and 2 at the external posterior angles). The hemielytra are basically olive-brown. The immature adult male has approximately the color of the mature female, while the mature male is darker, its cuneus from yellowich becoming red with a blackish external margin (Barbagallo 1970).

Host plants. *C. trivialis* is a polyphagous species, feeding on herbaceous as well as woody plants of

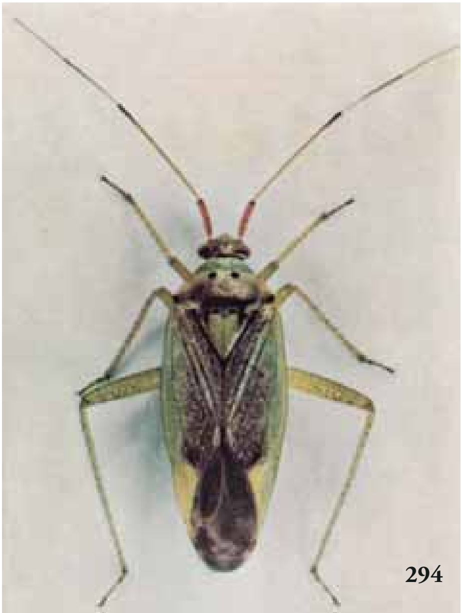

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Fig. 294. *Calocoris trivialis* adult female (Barbagallo 1970).

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various families. Among the cultivated trees, it has been frequently observed on orange, tangerine, clementine and olive, while among the wild herbaceous plants on nettles, *Urtica membranacea* and *U. urens,* on *Vicia sativa, Sonchus oleraceus* and *Parietaria officinalis* (Barbagallo 1970, Pontikis 1974). Barbagallo (1970) observed it also on apricot and *Pittosporum tobira,* and only exceptionally on lemon, while Pegazzano (1958) reported injury to peach trees in the area of Livorno, Italy. In Crete, Gerakaki et al. (2007) and Kalaitzaki et al. (2012) recorded it also on *Mercurialis annua, Malva silvestris* and *Sinapis alba.*

Life history and damage. Its life history has been studied in detail in Sicily on citrus by Barbagallo (1970). According to that work, the insect on citrus, has one generation per year. Larvae and adults behave as typical flower feeders, piercing and sucking preferably flower buds and inflorescences. It seems that the larvae prefer herbaceous plants, and the adults trees. It overwinters in the egg stage, in cracks and fissures of dry and especially exposed wood, where branches have been cut off at pruning. Hatching takes place from late January to early April. The young larvae descend the trunk to the soil and go onto herbaceous plants, preferably nettles of the genus *Urtica,* under or near the citrus trees. At that time, new growth of citrus has not started. The larvae pierce and such the tender terminal growth of *Urtica,* and especially the male inflorescences of *U. membranacea dioica.* They reach the adult stage from late March onwards, and as adults return to the trees where, in April and May, they feed on tender new growth (flowers, buds, leaves, shoots). Larvae that hatch late, find tender new growth on the trees to feed on, and may remain there, without descending to the herbaceous plants below. After having laid their eggs on exposed wood from late April to mid-June, the adults die. On olive in Sicily, the insect lives and develops approximately as on citrus (Barbagallo 1970).

In eastern central Greece, Pontikis (1974) observed the first larvae on nettles in and around olive groves from February onwards. He reports that when the olive inflorescences start to develop, larvae of late instars abandon the herbaceous plants and return to olive trees, mostly from mid-March to early April, where they feed on the axes of developing inflorescences, causing them to wither and drop. Drosopoulos (1993), also in central Greece, observed not only adults but also second- and third-instar larvae on olive trees, yet in much smaller numbers than on the herbaceous undergrowth of olive

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groves. He recorded second and third instars in February and March, and adults mainly from late April to mid-May. In coastal northern Greece, Navrozidis et al. (2001) observed hatching to occur from mid-February to mid-March. After feeding for a few days on olive buds the young larvae descended on neaby nettles of the genus *Urtica* on which they kept feeding, growing, and became adults. The adults returned to the olive trees synchronously in late April. They pierced and sucked the floral axes of developing inflorescences, then oviposited in April and May in cracks and fissures of the bark of the trunk of olive trees. Thus, seasonal history on olive in Greece is similar to that on citrus and olives in Sicily. In olive groves of the northern coastal part of western Crete, Gerakaki et al. (2007) sampled the bug's population twice a month during the first half of 2007, by shaking the foliage of olive and of the herbaceous weeds in the grove. High populations of the insect were found from late February to mid-April on the weeds, especially *Mercurialis annua* and on a nettle (*Urtica* sp.), and considerably lower ones on the olive trees. Two years later, in the same general area, weekly samplings by Kalaitzaki et al. (2012) also showed the larval population to be substantial on the herbaceous weed *M. annua* in and around the olive grove from early February to late April, with high densities from mid-February to mid-April. Populations on the nettles and *Sinapis* sp. were much lower, and on *Parietaria officinalis* even lower. Adults were collected on olive trees from mid- to late April, shortly before the blooming time of the trees. During that period the peak of the adult insect population on the weed *M. annua* coincided with that on the olive trees, but was more than twice as high.

In an orange orchard of the same area of Crete, the insect's larval population on the weeds as a whole was similar to that in the olive grove, but occurred approximately one to two weeks earlier. Adult insects also appeared earlier that in the olive grove, and remained longer on the plants, i.e. from mid-March to virtually early May on the weeds and from mid-March to late April on the orange trees. Their population on *M. annua* was by far denser than on the orange trees, as was the case in the olive grove (Kalaitzaki et al. 2012).

On olive, damage consists in blossom drop. Barbagallo (1970) considered this drop not serious in the Puglia region of southern Italy, because olive blossoms are usually abundant. Thus, even a high percentage of blossom drop allows enough sound flowers on the tree to give a good yield of olives. D. Pontikis (personal communication) in central Greece, observed an interesting case in an olive grove, when

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the vetch, *Vicia sativa,* which had been sown in the grove as a green manure was ploughed under in spring. The larvae of *C. trivialis* had then to abandon the vetch. They returned to the trees en masse and caused heavy damage. The adults that were formed in mid-April caused less damage than they did as larvae. A possible explanation is that at that time the floral axes had hardened, and the adults pierced and sucked mostly individual flowers and apices of inflorescences. Drop of whole inflorescences was thus limited. For decades, some Greek scientists believed that *C. trivialis* is responsible for heavy blosson drop in many olive groves. According to L.G. Tzeiranakis (2001 unpublished report), destruction of olive inflorescences at certain localities of central Crete coincided with dense populations of the insect on the trees. Navrozidis et al. (2007) also reported that adults cause heavy blossom drop and, therefore lack of olive fruit. On the other hand Drosopoulos (1993), on the basis of experiments in which he caged larvae and adults of this insect on olive twigs, rejected the view of previous authors that *C. trivialis* is a pest of olive trees. Gerakaki et al. (2007) consider this bug a secondary pest of olive in western Crete, causing economic injury only locally and occasionally. Also, Kalaitzaki et al. (2012) have not recorded serious injury to olive inflorescences when there was wild herbaceous undergrowth in the grove, the adults preferring to feed on such herbaceous plants. Only in years with exceptionally dry spring and no weeds in the grove, has this insect caused damage of economic importance to olive trees. Kalaitzaki et al. (2012) conclude too that this insect should not be considered potentially damaging to the fruit setting of olive or orange when there are sufficient weeds around during the prebloom and blooming stage of the trees for the insect to feed on. The conflicting views on this insect's status as a pest of olive certainly points out to the need for further experimental work, paying attention to the identity of the species under study. A related species of the same genus, *C. norvegicus* (Gmelin), has great morphological similarities with *C. trivialis* and misidentification should be cautioned about.

C. trivialis is able to also injure certain fruit trees other than olive and citrus. Pegazzano (1958) reported injury to peaches and fruits of other trees of the same genus by punctures in the fruit mesocarp. She also proved the insect's punctures caused lithiasis to pears. In eastern Sicily, larvae caused necrosis to apricot leaves, accompanied by oozing of gum.

Control. Where there is proof that the insect causes economic damage,

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a spray is recommended in spring before the blooming of olive. In central Greece, one spray in March with a suitable organophosphorous insecticide reduced the drop of inflorescences and gave a satisfactory olive yield (Lazaros and Marangoudakis 1976). Gerakaki et al. (2007) and Kalaitzaki et al. (2012) referring to western Crete, conclude that chemical control should be applied only when populations of the bug are dense, olive flowering is poor, and the herbaceous wild vegetation in the grove has been eliminated or dried out early, because of hot and dry weather.

Liothrips oleae **(Costa)** *(Phloeothrips oleae)* **(Thysanoptera, Phloeothripidae)**, comm. **black olive thrips**

Adult. Melis (1935a,b) described in detail the morphology of all stages of the life cycle. The male is 1.4-1.8 and the female 1.9-2.5 mm long. Silvestri (1939) gives greater dimensions. The body is shiny black. The wings of both sexes are 1 mm long and do not reach the end of the abdomen. The head is subrectangular, one third longer than wide, and longer than the pronotum (Fig. 295).

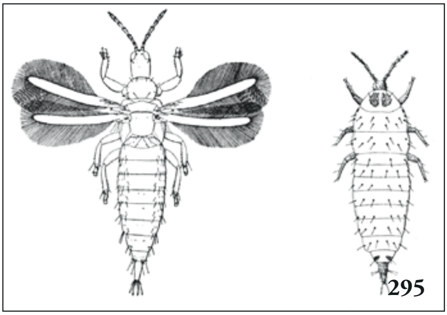

Fig. 295-296. *Liothrips oleae.* 295.Left adult female, and right larva (Silvestri 1939). 296.Deformations of leaves and flower drop as a result of earlier feeding punctures by the thrips (Sta. Firenze).

Egg. It is light brown, slightly kidney-shaped, and approximately 0.4 x 0.2 mm.

Larva. The neonate larva is whitish with red eyes. After some time it becomes greenish to yellow-green (Fig. 295). The grown larva is yellowish-white, sometimes reddish-yellow, with the head, the antennae, part of the pronotum, the legs and the end of the abdomen

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brown or dark grey (Melis 1935a). The larval instars are followed by an immobile prepupa and a pupa.

Host trees. Olive and *Olea chrysophylla.*

Life history and damage. *Liothrips oleae* is a multivoltine species. Along the northern Mediterranean coast where most of the detailed studies of its life history have been made, it completes three generations per year; a spring, a summer, and an autumn-winter one (Melis 1935a). In the Lucca region of central Italy, the adults of the third generation overwinter in various protected sites of the olive tree. Such sites are bark crevices, trunk cavities, cavities and galleries made by other insects, especially bark beetles, even fissures of tumors caused by the olive knot bacterium *Pseudomonas syringae* pv. *savastanoi* (Silvestri 1934, 1939), or bodies of *Saissetia oleae* killed by *Scutellista cyanea* Motschulsky (Tremblay 1981). According to Melis (1935a) it is only the adults of the third generation that overwinter. During sunny hours of relatively warm winter days, the adults leave their hiding places and come to the leaves to feed. As all plant-feeding Thysanoptera, the larvae and adults of this species, feed on the contents of surface cells of tender parts of the host tree. Reproductive maturity of overwintered adults occurs sometime in April. Eggs of the first (spring) generation are laid mostly in mid-May, and adults seen from late May to early July. Eggs of the second (summer) generation are laid from mid-June to early July, larvae develop from late June to mid-July, and adults are seen from mid-July to early August. Eggs of the third (autumn-winter) generation are seen in late September, larvae from early October, and adults mostly from late October to early November. There is overlapping between generations, especially between the first two. Thus, all stages of the life cycle can be seen during the growing season. In addition, many adults of the second generation may survive to the time adults of the third one appear. Silvestri (1939) gives slightly different periods covered by each generation in central, southern and coastal Italy, as follows: The first generation is completed in June, the eggs of the second generation are laid largely in July, and the third generation starts in August. A fourth generation is possible, in Italy when "temperature and humidity conditions are favorable" (Silvestri 1939, Tremblay 1981), as well as in the warmest regions of Spain (Arroyo Varela and Lacasa Plasencia 1986). The hiding habits of this thrips, especially in the adult stage, may well mislead those trying to determine the precise number of generations per year, as well as possible periods of dormancy.

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Without specifying the region, but probably referring to Spain, Arroyo Varela and Lacasa Plasencia (1986) state that, in addition to short-range movement of larvae towards new growth and of adults to and from their refuges, there are more regular dispersals away from the tree and the grove. In July, large numbers of adults may be seen flying, carried by convection air currents away from the trees they were born on. They ascribe this dispersal to favorable weather and crowding.

Larvae and adults feed on buds, leaves, tender shoots, flowers and fruits, causing surface necrosis and scarring of the various plant parts. Organs under development, in addition to surface necrosis and scarring, become deformed (Fig. 296). Other symptoms of injury are bud, flower and leaf drop, shoot deformation and short internodes. Young fruits, if too small, may also drop. Injury to buds and shoots, if extensive, may adversely affect the yield of the following year.

Control. Cultural measures that aim at keeping the trees in good condition, without infestation by bark- and wood-boring insects, and without tumors by the olive knot bacterium help in keeping the insect's populations low. When populations are dense, one application of an organophosphorous insecticide is recommended, preferably in early spring, mostly March, when the overwintered adults have become active but before they begin ovipositing. If necessary, a second spray may be done in the summer, when most of the population is in the adult stage.

***Lytta vesicatoria* L.** *(Cantharis vesicatoria)* **(Coleoptera, Meloidae)**, comm. **cantharis** and formerly **Spanish fly**

Adult. According to Isaakides (1936a), the body is cylindrical, 10-20 mm long, metallic green, with a copper or blue shine. The head is heart-shaped, the antennae are half as long as the body, the prothorax narrower than the base of the elytra, and the elytra long, covering the abdomen. Balachowsky (1962) gives a length of 12-25 mm

Larva. There is hypermetamorphosis in the larval stage. The young first-instar larva is of the triungulin type, can easily walk, and differs from the other instars which are unable to walk, although they can displace themselves little in the nest of their host.

Host plants. The adults are leaf-feeders and polyphagous. They infest preferably species of the Oleaceae *(Fraxinus, Ligustrum,*

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Fig. 297. *Lytta vesicatoria* adult, in natural size (Sta. Firenze).

Olea, Syringa), but are known to also infest Caprifoliaceae *(Lonicera, Sambucus, Symphoricarpus),* Salicaceae *(Populus, Salix), elm (Ulmus* sp.*),* certain other ornamental shrubs, and even begonias and Gramineae. Hosts of the larvae are species of wild bees of the families Bombidae and Apidae, often of the genus *Colletes,* in the nests of which they settle and grow.

Life history and damage. According to Isaakides (1936a), the life history of the preimaginal stages of this European insect is little known. It probably is univoltine or semivoltine. The adults appear in spring, usually in dense populations, and feed on the foliage and flowers of various "host" plants (above). They consume almost the whole leaf blade, leaving the veins. They first consume the distal leaves of shoots and twigs, especially of the upper part of the canopy. In Greece the adults are seen in May-June, sometimes in large numbers on elm, *Fraxinus* and olive. According to Della Beffa (1961) the adults are active in southern Italy already from late March, in northern Italy in mid-May, and in mountainous areas even in mid-June. In France the adults are active for approximately 2.5 months, and two periods of adult emergence have been observed, one in mid-May and the other in mid-June. One possibly concerns individuals of the univoltine and the other of the semivoltine life cycle. The presence of adults in the canopy of a tree can be detected even at a distance, due to their characteristic odor carried by wind (Isaakides 1936a). The eggs are laid in the soil at a small depth. The neonate larvae come out and search for nests of host insects, i.e. of wild bees, where they enter. The larva feeds usually on honey and pollen that the mother bee has stored in cells for its children. It is reported that the *Lytta* larva may consume even eggs or larvae of the host bee. The adults are reported to have caused considerable damage to the foliage of young olive trees and certain ornamental shrubs, in Greece (Anagnostopoulos 1939), and some other european countries.

Control. A spray with a contact or even a stomach insecticide will kill them. In the past, this beetle was well known in Europe because its elytra contain cantharidin used in pharmacy. In the past, an extract of dried beetles was used externally on humans as a rubefacient and

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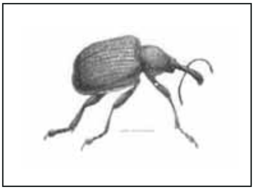
vesicatory, and even as an aphrodisiac. Consequently, the adults used to be collected in early morning and sold to pharmacists.

Rhynchites *(=Coenorrhinus)* ***cribripennis*** **Desbrochers** *(R. ruber* Schilsky) **(Coleoptera, Attelabidae)**, comm. **olive weevil**

Adult. Silvestri (1912a) gives details of the external morphology of the adult and larva. The adult (Fig. 298A) is 5.5-6 mm long, rostrum included. The width at the base of the elytra is approximately twice that of the prothorax. Every elytron has ten longitudinal grooves. The body is brick red, covered dorsally with a grey pubescence and ventrally with a whitish one, while the eyes, mandibles, mesothoracic episterna, and abdomen are black. The last three antennal segments are distinctly wider than the rest. The antennae are based at approximately the middle of the rostrum.

Larva. All larval instars are apodous. The fully grown one is straw-colored, with the anterior part of its head brick red, or rusty, and the mandibles black. Its body is arched and measures 7 x 2.8 mm when stretched, and 4.5-5 x 2.8 mm when arched.



298A

Fig. 298. *Rhynchites cribripennis*. A.Adult (Sta. Firenze, da Ribaga). B.Injury to olive fruits as seen in mid-September (photo M.E.T.).

Host plants. The life cycle is completed only on olive and oleaster, but the adults seem to feed also on other Oleaceae (Balachowsky and Hoffmann 1963, Monaco 1986). According to Zanardi (1967), the oleaster seems to be the best host.

Seasonal history and damage. This insect is semivoltine. According to Monaco (1986), who most probably refers to Italy, the insect on olive trees passes the first winter mainly as a fully grown larva in the soil, and the second winter as an adult also in the soil. Overwintered

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adults come out of the soil from late April to late May and fly to the foliage of olive trees where they feed for several weeks first on tender leaves and apical parts of shoots, then on small young fruits. Their feeding holes in fruits (Fig. 298B), cause early fruit drop. In southern Italy, such fruit drop occurs mainly in early July and can be serious. From late July to late August the female, after boring with its rostrum a hole in the mesocarp to reach the outer part of the endocarp, which usually it erodes superficially (Silvestri 1912a), inserts an egg. The female plugs the opening of the oviposition hole with small pieces of mesocarp. Tissue proliferation that follows adds to the closing of the opening. The young larva hatches in approximately ten days, bores through the endocarp which is already lignified, and reaches the seed which it devours completely. Only one larva may develop in a fruit. Upon completion of its growth, sometime in October or November, the fully grown larva abandons the fruit and overwinters in the soil. Pupation takes place in the soil at the end of the following summer to early autumn, namely in late August and in September. The adult is formed in winter, and comes out of the soil at the end of April or in May, thus completing its life cycle in two years, (Monaco 1986). This seasonal history is in general agreement with those given by Silvestri (1912a) on olive, and Zanardi (1967) on oleaster. According to Zanardi's brief report, oviposition on oleaster in Sardinia occurs in July, the fully grown larvae abandon the wild olives and enter the soil in September, pupate the following summer, and the adults emerge the following spring. Zanardi mentions that larval development in olives is slower than in wild olives.

On the island of Zakynthos (Zante), to the west of southern Greece, Lykouressis et al. (2001) recorded the adult population on the foliage of non-irrigated olive trees of the small-size-fruit cultivar Koroneiki, by beating twigs weekly over a net. They thus captured adult weevils from late April to late July, with maxima in mid-June 1994 and early July 1995. They also recorded larvae in the endocarp from the end of June to mid-September, and in the endosperm or embryo from mid-July to mid-October (D.P. Lykouressis, pers. comm.). In addition to the periods of activity, this insect's semivoltine seasonal history includes, therefore, a long period of larval dormancy in the soil, then a shorter period of adult dormancy also in the soil, then a rather long pre-oviposition period from mid-spring to mid- or late summer on the tree. Earlier reports that this insect is univoltine, are not supported by convincing data.

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Silvestri (1912a) gave details of the shape and dimensions of erosions to foliage and fruit made by the adults, some of which are characteristic. He also gave nice drawings of the various stages of the insect, of erosions to the fruit made by adults and larvae, of seeds eroded by larvae, and of fruits with larval exit holes. In fruits of certain but not all cultivars, the mouth (opening) of the adult feeding hole on the fruit is suberized and acquires a characteristic, dark, crater-like appearance. Feeding holes are usually one or two per fruit, but several and as many as 20 or 30 are reported for southern Italy by Silvestri. The injury caused by the adult feeding on tender shoots and leaves, may destroy buds and shoot tips, or deform leaves, but generally is of no economic importance. By contrast, the adult feeding holes injury to fruits causes early fruit drop and can be serious when the insect population is dense. According to Isaakides (1936a), fruits eroded by the adults either drop soon after being injured, especially if eroded early, or stay for sometime on the tree, become black, dry out, and drop at the slightest shaking of the branches. Crop losses of 30-80% have been reported for certain groves of Greece, and 40-70% for southern Italy and Turkey (Isaakides 1936a, Monaco 1986). Monaco (1986) mentions that additional early fruit drop may be caused by the fungus *Camarosporium dalmaticum* which is inoculated in the insect feeding holes by the midge *Prolasioptera berlesiana.* Injury to fruit by the larva consuming the seed is considered by Silvestri (1912a) to be less serious than that caused by the adult, because it does not usually result in substantial early fruit drop. This of course concerns oil cultivars, as the oviposition hole renders a table olive unsuitable for the market. Fortunately, table olive cultivars, having generally large fruits, are not injured by this insect to an appreciable extent, at least in most regions. *R. cribripennis* has been a pest only of cultivars bearing small-size fruit, growing in dry, non-irrigated soils, usually in hilly areas. In Greece, the olive cultivar Koroneiki, which is infested by this insect more often than most other cultivars, has the smallest fruits, which are approximately the size of oleaster fruits. On the island of Thassos, off the east coast of northern Greece, where the insect develops on a local cultivar with medium-size fruits, the female insect selects the smallest fruits of a tree to oviposit (D.A. Prophetou-Athanasiadou, pers. comm.). This insect's economic importance has been reduced since the advent of synthetic organic insecticides.

Control. On trees which had injury by this insect in the previous two years, and show erosions on the leaves in spring, a spray in

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recommended right after bloom, with a contact insecticide, preferably organophosphorous. For a few trees, shaking of the branches early in the morning and collecting the falling weevils on a sheet of cloth underneath, is a useful measure of control.

Otiorrhynchus cribricollis **(Gyllenhall)** *(O. terrestris)* **(Coleoptera, Curculionidae)**

For information regarding species of the genus *Otiorrhynchus* in general and *O. sulcatus* F. which occasionally infests olive, see insects of grapevine.

Adult. According to Arambourg (1986c) who gives his bibliographical source(s) only at the end of each chapter of his 1986 book, the adult *O. cribricollis* is oblong, 7-8 mm long, brown, sometimes tending towards reddish, shiny. The elytra have on the interstriae a line of short hairs, arched, slightly raised. The rostrum is short and thick.

Larva. It is light yellowish-grey, with a ferrugineous head and reddish-brown mandibles. The body is generally arched. Its final length is 8-9 x 2.5-3 mm, but artched it is only 5-6 mm long. It is terricolous.

Host plants. It prefers olive, but attacks also many other plant species, such as apple, peach, almond, citrus, ornamental plants, *Ligustrum ovalifolium,* cotton, artichoke, and many other. The larvae feed also on the roots of alfalfa (*Medicago sativa), Artemisia gallica, Melia* sp., and other.

Life history and damage. Accorcing to Arambourg (1986c), it is univoltine. Overwintering is generally in the larval stage which continues its growth and development in winter, passing through 10 instars until the second half of May under Mediterranean conditions. Adult emergence starts in the last decade of May and continues throught June. The adults begin a period of intense feeding activity, ascending on the plants at night and causing characteristic erosions to the leaves. Oviposition starts in September and continues for practically three months, after which the adults disappear gradually. The young larvae emerge at approximately mid-September. A small percentage of adults may remain active in part of winter, depending on the climatic conditions, and lay again towards February. This explains the presence of young larvae in April-May.

The larva feeds on roots of herbaceous plants. Therefore, the

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injury they cause is very small compared to that caused by the adults. Under unusually high population densities, the adults may cause more or less total defoliation of olive trees, as observed in Algeria, Tunisia, Italy and Spain.

Control. Arambourg mentions that no control method has been proposed. However, applications of organic contact or even stomach insecticides should be effective against the adults, applied as soon as erosions of the leaves are considerable.

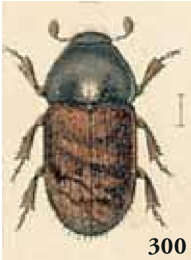
Hylesinus oleiperda F. (*H. toranio*) (Coleoptera, Scolytidae)

Adult. According to Touzeau (1963, 1965), the adult has an oval body, 2.5 x 3.5 mm long, totally black, covered with a dense reddish and blackish pilosity, which makes the adult look dark brown. The pronotum protrudes backwards between the bases of the elytra. The antennae have a club of three segments (Fig. 299). This distinguishes this species from *Phloeotribus scarabaeoides* another bark beetle which also infests olive and other Oleaceae. According to Avidov and Harpaz (1969) the legs and antennae are red.

Larva. It is white and, when fully grown, 3 mm long. The larva lives and grows inside the tree.

Host trees. Olive and other Oleaceae, such as *Fraxinus excelsior, F. ornus, Ligustrum vulgare* and *Syringa vulgaris.* Less frequently it infests some nonoleaceous trees such as *Quercus* sp., *Fagus silvatica,* and *Juglans nigra* (Russo, 1932, Touzeau 1963, Graf 1977, Jarraya 1986). It damages mainly olive and species of *Fraxinus.* Jarraya (1986) states that, where olive is grown, it lives on this tree, while in temperate Europe it lives on the various other Oleaceae given above.

299



300

Figs. 299-300. 299.*Hylesinus oleiperda* adults in dorsal and side view (photo N.T. Papadopoulos). 300.*Hylesinus fraxini* adult (Calwer 1893).

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This species' similarity with *Hylesinus varius* F., suggests caution as to the species distribution and ability to live on nonoleaceous trees.

Life history and damage. Its range of distribution is wide, from the United Kingdom to the Caucasus, the Mediterranean coast, Middle East, Chile and Argentina (Russo 1932, Jarraya 1986). Despite the fact that this bark beetle is harmful to olive in a number of countries, its seasonal history has not been studied in sufficient detail. By most authors it is reported as univoltine, and by a few as bivoltine in certain regions and localities, or when growing in pruned-off branches. In Greece according to Isaakides (1936a) it completes one generation per year. Perhaps in certain areas part of the population completes a second generation in half-dry branches. It overwinters as a fully grown larva at the end of its gallery. It pupates at the same site and becomes adult in spring. The adults appear in May. They bore feeding chambers in 1-3-year-old twigs, on the underside of a twig axil. The feeding chamber has an approximate diameter of 3 mm. After they feed and mature sexually, the females bore maternal galleries (reproduction galleries) in branches, where the bark is smooth. In young trees they bore maternal galleries even in the trunk. They preferably select weakened and half-dead branches, but may also infest healthy ones, especially of certain olive cultivars. According to Isaakides (1936a), the maternal gallery consists of a prodomus 3-5 mm long, followed by the main gallery which has one or two branches, and a direction usually vertical to the branch axis. The gallery is relatively short, 6-13 mm. Along the upper (towards the branch apex) and the lower side (towards the branch base) of the gallery the female bores small chambers (cells), and lays an egg in each. According to Isaakides (1936a), the maternal gallery has one branch in healthy and vigorous olive branches, and two (as in fig. 303) in half-dead branches. Touzeau and Balachowsky (1963) mention that the maternal gallery has two equilong branches, without specifying whether it is the rule. Mating occurs when the female wanders along twigs and branches to find a proper site for the maternal gallery, or when it has bored the prodomus and stays with her abdomen protruding from the gallery entrance. *H. oleiperda* is monogamous. While the female bores the gallery, the male helps by pushing the frass out. Every female bores more than one maternal gallery and lays from a few to a few decades of eggs in each, depending on the diameter of the branch and the species of tree. The larval (daughter) galleries are at first vertical to the maternal one, but later deviate from their original direction

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and often cross one another. They are in the bark as well as in the sapwood. The larvae complete growth in autumn, widen the end of their gallery to a pupation chamber and overwinter. They pupate and become adults the next spring. Isaakides (1936a) mentions that in cut-off semi-dry branches the insect may have a partial second generation. In such a case, the first generation will cover the period from March-May to July-September, and the second one from August-September to May-June. The bark above the larval galleries dries, becomes hollow, wrinkled, and torn in many parts. Finally an oval, hollow, rusty zone appears, which is characteristic of the attack by this beetle.

According to Russo (1932) who studied it in southern Italy and Sicily, it completes one generation per year in live trees and two generations in cut twigs and branches. Where one generation prevails, the insect overwinters as a reproductively immature adult, usually in a feeding chamber on the tree. The adults come out of their shelters from late April to early June, mostly in May, and soon bore feeding chambers at the axils of shoots and twigs. After they have fed and matured sexually, they search for twigs and branches suitable for them to bore maternal (reproduction) galleries. They usually select weakened and half-dry branches, but can infest also lealthy branches, especially of certain olive cultivars. In young trees maternal galleries are made even in the trunk. The females oviposit mostly in June. The new adults emerge the following May, even if the eggs have been laid late, in July-September. In France, also one generation is reported by Touzeau (1963).

On the Dalmatian coast, Croatia, Tominic (1967b) observed that during dry and hot summer periods the adults tend to infest thin healthy twigs, while during more humid and moderately warm summer periods they infest larger, partly-damaged twigs. In large twigs and small branches the larvae seem to be nourished better and grow faster than in thin twigs. The adults then appear in late winter and are considerably larger than those from thin twigs, which emerge much later, in May-June. In the thin twigs oviposition occurs from mid-June to late September, with a peak in the second half of June and in early July. The development of the insect stops during the hot spells of summer (Tominic 1967b).

In Tunisia, Touzeau (1965) reported that the insect completes two generations per year. Overwintering occurs as larva, the instar not being specified. Pupation occurs from mid-March to late May. In

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1965, the adults emerged from early May to late June. Those adults of the overwintered (second) generation lived for approximately 3 months. Young larvae of the first generation were observed from early May onwards. They grew in summer, and pupation started in the first half of July and continued until mid-November as a result of the long period of egg laying. The adults of this first generation emerged from early August to early December. They laid the eggs of the second generation from mid-September to mid-December and the larvae overwintered.

In the Tadla region of Morocco, Graf (1977) recorded one generation per year. The experimental grove was at an elevation of 600 m, with an arid to semi-arid climate, a hot dry summer and a cool winter. The adults emerge when the olive trees bloom, in the first half of May, and emergence lasts 6-8 weeks. The adults are long-lived and are seen as late as early December. Oviposition covers the whole summer and part of autumn, from early June to early November, with 50% of the eggs being laid by mid-August, and 90% by mid-September. Overwintering in Tadla occurs in all larval instars, with young larvae observed from mid-June to mid-January, “middle” instars from late July to late Fecruary, and last instars from October to mid-May. The first pupae were seen on 22 March.

On the Lebanese and Syrian coasts the insect apparently also completes one generation per year. It overwinters as larva, pupates in the larval gallery in early May, and the adults start appearing in mid-May (Talhouk 1969). In those two countries it mostly attacks weak trees.

Russo (1932) considers this species to be the most harmful bark beetle of olive, and one of the most harmful insects of the olive tree. The adult feeding chambers in young shoots of the season weaken and finally dry out the parts distal to the chambers, or the shoots are broken by wind, with their future production being lost. However, the main damage is caused by the larvae. Their galleries slow the circulation of sap, and in extreme cases sap flow may stop above the infested site. Not only weakened, but also healthy trees are infested. Twigs or small branches, 1-3 cm in diameter, suffer bark necrosis and are killed. Larger-diameter branches are not usually killed, but have weak foliage and reduced yield. Russo (1932) mentions that branches will ultimately die if they house many galleries each. According to Touzeau (1965), brown spots on the surface of the bark, 1-5 cm

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long and of irregular shape, correspond to groups of larval galleries underneath. In Tunisia, in young trees less than 8 years old, the larval galleries in the trunk cause yellowing of the whole foliage, retardation of growth, and even death of the tree. Old trees are more tolerant. In most countries damage is not serious because of low population density of this beetle. Feeding chambers and maternal galleries, as well as larval galleries with adult exit holes, offer suitable shelters and egg laying sites for another pest, the olive thrips. Whether this represents economic damage is not clear. Russo (1932) considered it probable thast *H. oleiperda* vectors the olive-knot bacterium *Pseudomonas syringae* pv. *savastanoi.*

Control. Cultural measures to remove infested twigs and improve the tree's vegetative condition, especially in years of low rainfall, are recommended by some authors. For cultural and other measures see those recommended against *Phloeoptribus scarabaeoides* (below). On susceptible trees or cultivars with high insect population densities, insecticides are applied against the adults. Jarraya (1986) suggests a spray with a contact insecticide when the adults begin to emerge and a second one two weeks later.

A related species, *Hylesinus (Leperisinus) fraxini* (Panzer) (Fig. 300) infests usually species of *Fraxinus,* and occasionally the olive in a way similar to that of *H. oleiperda*. Russo (1932) mentions two more bark beetles, also of the Hylesini infesting olive: *Phloeophthorus cristatus* Fauvel reproducing in cut twigs in the Marotta area of Italy, and *P. rhododactylus* Marsham in Sicily.

Phloeotribus scarabaeoides Bernard (Coleoptera, Scolytidae), comm. olive phloeotribus

Adult. According to Isaakides (1936a), the body (Fig. 301) is dark brown to almost black, and is covered with a grey pubescence. The antennae, the tarsi, and sometimes the tips of the elytra, are reddish. The hind margin of the pronotum is curved forward along each elytrum. According to Russo (1938), the adult body is full black, short, subcylindrical, 1.85-2.6 mm and most frequently 2.36 mm in the female, and 1.48.-2.65 and most frequently 2.25 long in the male. The head is black, with the vertex and genae black-brown, and the antennae brown. Each of the last three antennal segments has a side lamelliform extension. When these blade-like extensions touch one

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another the antenna looks clubbed, and when they are held apart the antenna looks trifid apically. Russo gives great details of the external and internal morphology of this insect.

Larva. The grown larva has a yellowish head, yellow-ferruginous frons and labrum, and measures 5.8 x 2 mm when distended, but is only 2.37-3.5 mm long when curved.

Host trees. *Olea* and other Oleaceae (Balachowsky and Mesnil 1935, Russo 1938). Along the Mediterranean coast it is found mainly on *Olea,* and also on some species of *Fraxinus,* such as *F. dimorpha* Coss. and *F. oxyphylla* Marsh., while further north it infests mainly *Fraxinus, Ligustrum and Syringa* (Jarraya 1986).

Life history and damage. This species occupies an intermediate position between the species that attack and kill vigorous living trees, and those that live only on dying trees (Neuenschwander and Alexandrakis 1982). The number of generations per year varies with the region. It is reported 3 per year in Greece (Isaakides 1936a, Anagnostopoulos 1939), 2-3 in France, 4 in southern Italy and in Algeria, while even a 5th generation should not be excluded in Oranie and the Atlantic coast of Morocco (Balachowsky 1963). Talhouk (1969) mentions probably 4 generations in Lebanese and Syrian coastal areas. In the Sahel of Sfax region of Tunisia, Arambourg (1964) recorded 4 generations on live olive trees. On weak trees Jarraya (1986) reports 2 to 3 generations in southern France, 4 in southern Italy and northern Africa, without excluding a 5th one in Oranie and the Atlantic coast of Morocco. In contrast, in southern Spain the insect completes only one generation per year (Gonzalez 1990, Gonzalez and Campos 1993), and in Tunisia on cut branches also one or eventually two generations (Jarraya 1986). It may be that the availability of recently cut branches in the grove affects voltinism in certain regions, by favoring reproduction and larval growth.

According to Isaakides (1936a), this bark beetle in Greece overwinters mostly as a reproductively immature adult, in feeding chambers and maternal (reproduction) galleries. A smaller portion of the population may overwinter also as a larva or egg, from late, October-November ovipositions, thus forming a partial fourth generation. The adults that overwinter (third generation) become active in mid-February in the warmer localities, feed, mature sexually, mate, and, after boring maternal galleries, the females lay their eggs. Individuals from late (autumnal) ovipositions, that overwinter as eggs

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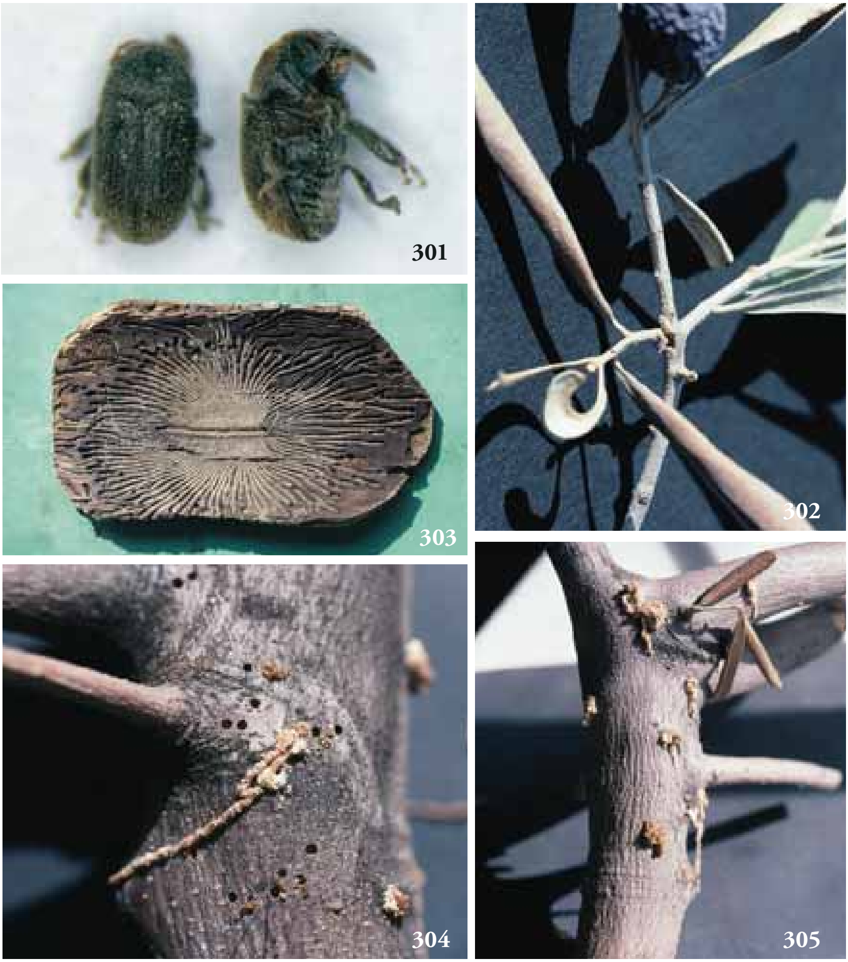

Figs. 301-305. *Phloeotribus scarabaeoides.* 301.Adult in dorsal and side view (photo B.I.K.). 302.Feeding hole of adult at the axilla of an olive twig. 303.Inner side of olive bark showing a maternal gallery (horizontal) in the middle, and many larval (filial) galleries starting from it. 304. Exit holes of adults on the bark. 305. Frass that came out of entrances of maternal galleries. (photo B.I.K.).

or larvae, complete their development in spring and emerge as adults in May-June, at approximately the same time with the adults of the first (spring) generation. The adults of the second generation appear in July-August and of the third one October-November. According to

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Anagnostopoulos (1931, 1939), the eggs of the first generation are laid in February, of the second generation in mid-May, and of the third one in August, while the adults of the first generation emerge in mid- to late April, of the second generation in July, and of the third one in October. On Corfu, Sarakomenos (1920) mentions also 3 generations per year, with adults appearing in early May, from late June to early August, and in October.

In the Sahel of Sfax of Tunisia, the overwintering population was composed of adults of the second and third generations and of larvae of the fourth one (Arambourg 1964). Adults of the first generation emerged in June, of the second generation were seen from mid-August to late September and of the third one in November. In that region, in normal olive groves, the insect breeds only in branches and twigs cut off at pruning time and usually left in piles near the groves.

In Crete, oviposition and larval growth take place mostly in dying branches cut from the trees at pruning time (Neuenschwander and Alexandrakis 1982), as in southern Italy and Sicily. After emergence, the adult beetles feed on fresh twigs before dispersing in early summer in search of dying olive wood to reproduce. In Spain dispersion for 3.5 km has been recorded (Gonzalez and Campos 1993, 1995).

According to Isaakides (1936a), the adults feed on bark while boring feeding chambers in the axils of one- to two-year-old twigs. The feeding chamber (Fig. 302) has a diameter slightly larger than that of the beetle. It is usually 2-2.5 mm wide, up to 5 mm deep, and directed proximally (towards the base of the twig). After feeding and maturing sexually, the females go to suitable branches to bore maternal galleries in which to oviposit. They generally select weak or half-dead branches, branches broken by wind or other causes, or freshly cut-off branches with smooth bark and usually a few years old. When the population density of laying females is dense, maternal galleries are bored even in large branches and where the bark is rough. Mating occurs when the female searches for a suitable site to bore a maternal gallery, or when it bores the prodomus of the gallery and her abdomen protrudes to the outside. *P. scarabaeoides* is a monogamous species. The male helps by pulling the frass out of the gallery. The prodomus has an oblique distal orientation until it reaches the sapwood. Subsequently the gallery proceeds between bark and sapwood distally, parallel to the branch axis for approximately 3 mm. Then one of the branches of the gallery is bored at an approximately right angle to the axis of the tree branch. Along

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the proximal and distal sides of this gallery branch, cavities (cells) are dug out, in each of which an egg is laid. Subsequently the female returns to where it started and bores the second branch of the gallery in the opposite direction to the first branch. Thus, the two branches of the gallery are on a straight line or almost so, with the prodomus in the middle (Fig. 303). In olive branches of a larger diameter each half of the maternal gallery (each branch of it) is 25-30 mm long, and is perpendicular to the axis of the olive branch. In branches of a smaller diameter the maternal gallery is shorter and at an angle to the branch axis, so that the two gallery branches are not likely to meet. While boring the maternal gallery the female mixes the frass with saliva and with the help of the male pushes it to the outside. Some frass remains hanging at the entrance of the gallery and is easily seen (Fig. 305). The pair requires approximately 40 days to bore a maternal gallery, and 50-80 eggs are laid in it. Arambourg (1964) recorded in Tunisia only a mean of 15.3 eggs per maternal gallery, with a maximum of 38 in olive branches 36-48 mm in diameter. Every female bores one or two such galleries and subsequently the pair of beetles dies. The larval (filial) galleries are bored between bark and sapwood. Those closer to the prodomus of the maternal gallery, i.e. closer to the middle of the gallery, are perpendicular to the gallery and parallel to one another so that they do not meet (Fig. 303). The others deviate from perpendicularity, so that they also do not cross one another as their diameter grows together with the growth of the larvae that bore and grow in them. The larval stage lasts approximately 45 days. The fully grown larva widens the end of its gallery to form a pupation chamber. The pupal stage lasts 20-25 days and the adult comes out through the bark after boring with its mandibles a circular or almost circular hole above the pupation chamber (Fig. 304). Subsequently, the young adult bores its feeding tunnel (chamber) on the same, on a neighboring, or on a distant tree.

Russo (1938) studied this insect in Sicily and southern Italy, and extended his observations also to the northern limits of olive culture in Italy. He found that 3 regular generations and a facultative 4th are produced there: a vernal, an aestival, an aestival-autumnal, and a hibernal-vernal one. Overwintering occurs mostly in the immature adult stage, as reported for Greece by Isaakides above. Russo (1938) reports that overwintering is not done in feeding chambers that had been bored during the warm season by other beetles, but in overwintering chambers bored in olive twigs by the beetles about

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to overwinter. These chambers are similar to the feeding ones. The overwintered beetles become active in February, feed, mature sexually, and the females go to sickly or half-dead branches with a smooth bark to bore maternal galleries and start ovipositing as given above. The first generation is completed in May-June The second generation is completed from mid-June to August, with the adults emerging in mid-August, and the third generation is completed September-October. Eggs of the facultative fourth generation are laid the first half of November, probably by some females of the second or the third generation. The larvae develop slowly in late autumn and winter and complete their growth in spring, emerging as adults in May-June, at about the time the adults of the first generation appear.

Damage to olive trees is due to the killing of twigs caused by the feeding chambers and the further weakening or death of branches by the larval galleries. The feeding chamber usually causes the death of the twig distal to it, and often its falling off during a strong wind or rain. Larval galleries weaken or even kill branches. However, the insect's preference for ovipositing in already weakened or cut off branches reduces its importance as a pest in many but not all countries. Balachowsky (1963) considers it an important pest of olive in southern France, Italy, Spain and North Africa, especially Algeria, Morocco and even Tunisia, and points out that injury to young olive groves is less frequent. In Spain, tree injury is caused during the feeding periods of overwintering beetles before their dispersion flight, and by the newly emerging beetles throughout summer (Gonzalez and Campos 1993). Gonzalez and Campos (1994) consider this bark beetle as one of the most economically important phytophagous insects in present day olive culture, because the damage it causes to young branches results in loss of fruit and flowers. Such loss of fruit may be considerable in the most-infested trees. The adults' feeding and overwintering chambers offer suitable shelters and oviposition sites for the olive thrips. Whether this represents economic damage is not clear.

Control. The recommended control measures are mainly cultural and, to be effective, should be applied on a relatively large scale. Among them are: Measures that keep the trees vigorous. Destruction of non-productive weak trees and of trees heavily infested by this bark beetle. In winter, removing by pruning the half-dead or dead branches and twigs and taking them away from the grove by mid-

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February, or burning them. Also, keeping them for at least six months in a warehouse with a fine mesh in the windows so that the beetles cannot come out and ultimately die. A bad habit is to keep near the houses half-dead or dead olive branches after mid-February, to be used as firewood, or to fence farm property. Such branches are a suitable substrate for the reproduction of the beetle and ultimately result in heavy damage to nearby olive groves. The use of “branch traps’ is another measure. Uninfested branches that are removed at pruning time in winter, are kept in piles in the grove until April for the adults to oviposit in. When the presence of frass on the bark shows that the females have completed their maternal galleries and laid their eggs, these branch traps are collected and burned (Isaakides 1936a). According to other authors, the collection and burning of the branch traps should be done earlier, within March (Anonynous 1973). The use of branch traps needs care, because if we burn them very early, some adult females will escape and oviposit in healthy trees. If, on the other hand, we burn them late, many adults of the generation that developed in the branch traps will have emerged, therefore survived. Anagnostopoulos (1939) recommended that branch traps be placed in the grove more than once a year. Balachowsky (1963) also suggests placing trap branches in the grove to attract the ovipositing females. Jarraya (1986) also gives some of these control measures. In case of heavy infestation of trees that must be saved, a spray, right after the beginning of the appearance of the adults of the first generation, will help. Organophosphorous insecticides with relatively long residual action should be preferred. After ethylene proved to attract the adult beetles, trap trees sprayed with a mixture of an ethylene-releasing compound, such as 2-(chloroethylo) phosphinic acid, with an insecticide proved promising (Gonzales and Campos 1995).

***Dasyneura oleae* (F. Loew)** *(Corethra oleae, Cecidomyia oleae, Perrisia lathierei, P. oleae)* **(Diptera, Cecidomyiidae)**, comm. **olive leaf gall midge**

Adult. Both sexes are yellow, 2.2-2.5 mm long. The antennae are half the length of the body in the male, and one third in the female. The female abdomen is reddish (Coutin and Katlabi 1986).

Larva. It is yellow to light brown, or light reddish, with a brown bilobed sternal spatula (Fig. 307). As to body dimensions, Arambourg

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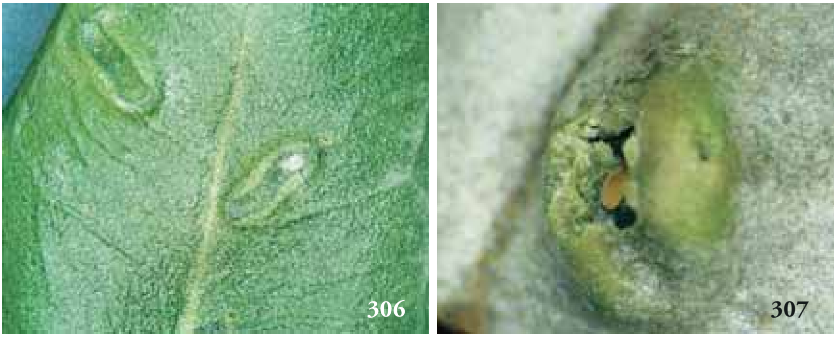
and Elant (1966) give 2.5 x 0.8 mm for the fully grown larva, whereas Coutin and Katlabi (1986) 0.5 x 0.25 mm probably for an earlier-instar. The pupa is orange red.

Host tree. Olive.

Life history and damage. The number of generations per year varies videly with the region, but also the authors. One to two generations have been reported in Italy, two or more in Lebanon, three in Jordan, and three to five in Syria (Arambourg and Elant 1966, Katlabi and Coutin 1979 and references therein). The work of Katlabi and Coutin (1979) in Syria supports the earlier publications by Angelini (1831) and Del Guercio (1909), and explains when this insect completes one and when two generations per year. The eggs are deposited, usually in small groups but sometimes singly, on very young plant parts, such as developing leaf buds, pedicels of closed flowers, or between closed



Figs. 306-307. *Dasyneura oleae.* 306.Two galls at the sites of larval galleries, as seen from the upper side of the leaf. 307.A gall partly opened on the underside of a leaf, for the light brown larva to be seen (photo D.S. Koveos).

flowers of developing inflorescences. The larvae mine tender leaves, floral axes, and individual flowers (seldom pedicels of newly formed fruits) causing galls and other deformities (Fig. 306). Arambourg and Elant (1966) found more than 100 oocytes per dissected female, but the number of eggs laid is not known. Population density varies with the region and year. These authors recorded in Syria an average of 3 larvae per inflorescence, and maxima of 13 per leaf, 8 per terminal bud, and 11 per inflorescence. They give details of larval and pupal behavior, as well as of the formation, size and appearance of galls. In Syria, according to Katlabi and Coutin (1979), the early winter

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is passed in the second larval instar in the larval gallery in an olive leaf. The larvae remain inactive until December or January. They resume their development in late January to early February, pupate in the leaves, and become adults from late February to May, and mostly in early March. Larvae that develop in leaves reach the end of their second stadium at the end of summer and enter diapause, while larvae that develop in floral axes do not diapause, grow faster, complete their growth, pupate and give adults in May. These adults oviposit on tender young leaves and a second generation develops in the leaves, the larvae of which enter diapause. Therefore, in regions, years, groves, or perhaps cultivars, where eggs are laid also on inflorescences, two generations must develop, one flower-boring in March-May, and a leaf-boring in summer. Such is the case in coastal regions of Syria with a maritime climate. When the eggs are laid only on leaves, one generation develops and part of the population may be semivoltine because of prolonged diapause. Prolonged diapause in approximately 30% of the population has been recorded in the interior of Syria, where the climate is continental. The second-instar larvae that develop in leaves enter an aestival-autumnal diapause which either extends to mid-winter, or is followed by a hibernal post-diapause quiescence.

In the Veronese area of northern Italy, the larvae in autumn undergo a dormancy and pass the winter in this state of inactivity. In the first warmths of the following spring they become active, continue to grow, pupate in the second half of April, and the adults emerge in May (Giraldi 1953).

Control. Injury by this midge to the leaves is not serious, therefore, no control measures are needed. Infestation of floral axes and of pedicels of fruitlets causes the shedding of flowers and desiccation and shedding of fruitlets. However, such fruit shedding, that usually occurs in June, is considered to be a useful thinning, when flowering and fruit set are abundant or even normal. Only in years of extremely low flowering and in a cultivar with a poor fruit set, as recorded in a grove in Syria, can a high proportion of destroyed flowers affect the yield to such an extent as to justify control measures. The only report of considerable injury to olive leaves in Greece comes from Roditakis et al. (2011), who observed it recently in a coastal locality of eastern Crete.

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Prolasioptera berlesiana **Paoli** *(Lasioptera berlesiana, L. brevicornis)* **(Diptera, Cecidomyiidae)**, comm. **olive fruit midge**

Adult. It is 1.4-1.6 mm long, generally brown with the abdomen lighter, and dark spots on the dorsum of the third to seventh uromeres. The female has a 0.5 mm long, two-segmented extensible ovipositor (Silvestri 1939). The antennae are composed of 18-20 articles or, according to other sources 11-21, each antennal segment, except the last one, being wider than long (Avidov and Harpaz 1969). The egg dimensions are 0.4-0.1 mm.

Larva. It is red or reddish, has a bifurcate sternal spatula anteriorly, and is 2 mm long when fully grown (Fig. 308). The pupa is 2 mm long, at first dark red and later dark brown.

Host plants and nature of food. Various opinions have been expressed as to what this midge mainly feeds on, and its association with the olive fruit fly *Bactrocera oleae* and the fungus *Camarosporium dalmaticum* (Thum.) Berl. & Vogl., known also as *Sphaeropsis* or *Macrophoma dalmatica.* The female *Prolasioptera* oviposits and the larva develops in a cavity in the mesocarp (flesh) of olives (Fig. 308). Having no terebrate ovipositor, the female cannot pierce the olive epicarp. Therefore, it searches for holes made by other insects or lesions caused by other factors. The most common, and probably the


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Figs. 308-309. *Prolasioptera berlesiana.* 308. Larva in a chamber of oviposition by the olive fruit fly, where the fungus has started to develop (brown mesocarp). 309.Spot of the fungus *Camarosporium dalmaticum.* A little to the right of the center there is an oviposition hole by the olive fruit fly (photo B.I.K.).

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most suitable, holes the female finds are the oviposition punctures of the olive fruit fly, whether in the chamber inside they contain a fruit fly egg (fertile punctures) or not (barren punctures). From those punctures a characteristic dark brown spot often starts, caused by the *Macrophoma* fungus. Most research to date has proven that the midge larva feeds on this fungus. The fungus, to enter the olive fruit, also needs a lesion on the epicarp. The most common such lesions are the oviposition punctures of the olive fruit fly. Thus, in olive fruits, all three organisms – fruit fly larva, midge larva, and fungus – are found together or in sequence. The egg incubation time of the midge is considerably shorter than of the fruit fly, thus the midge larva often hatches first, and often destroys the fruit fly egg with its mouth parts, whether sucking up its contents or not. This has led certain authors to consider the midge larva entomophagous and a predator of the fruit fly egg, while others to consider it mycophagous, feeding on the *Macrophoma* fungus, and perhaps also on fungus-infected olive mesocarp. Harpaz and Gerson (1966) have reviewed the respective literature up to that time and carried out field and laboratory experiments in Israel, to clarify the question of a possible biocomplex between the three organisms. Some of their conclusions are: (i) There is an association between the fruit fly and the *Macrophoma* fungus. In most of the *Macrophoma*-infected olives in nature, the initial infection occurred either through an oviposition puncture (regardless of whether barren or fertile), or through an exit hole of the fruit fly. However, the role of the fruit fly in disseminating the disease is rather passive, being limited to the opening up of invasion courts in the olives, through which the landing *Macrophoma* pycnidiospores may enter the otherwise impenetrable fruits. (ii) The role of the midge in the transmission of the *Macrophoma* disease was even less essential than that of the fruit fly in infecting olives with the fungus. (iii) The midge larvae were typically mycophagous. (iv) The concept of a biocomplex, i.e. of a trophic or symbiotic association existing between the three organisms, namely the olive fruit fly, the midge and the fungus, is no more than a misconception. The relationships between these three organisms appear to be more of a fortuitous and coincidental nature, rather than closely interdependent such as to warrant the use of the term “biocomplex” in its strict sense. A more appropriate term would perhaps be a “synoecism” with a usual, though not essential, sequence of occurrence on olives, starting with the fruit fly, and followed by the fungus and later by the

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midge. Tremblay (1991) concludes that the research data until that time support the conclusion that the larva of the midge is basically mycophagous, with a tendency for occasional zoophagy. It seems that the optimal condition for its development is the presence of a fruit fly egg, which it feeds on in its early life. Therefore, the olive fruit fly offers in nature most of the suitable holes needed for oviposition by the midge and the establishment of the fungus in the olive fruit. Therefore, there is a relashionship between the three species, but without one of the insects having a direct and indispensable trophic relationship with the other. For more details see Harpaz and Gerson (1966), and for a brief review of subsequent work Tzanakakis (2006). The view of a number of authors that the midge is a possible vector of the fungus, and/or a possible predator of the fruit fly, emphasizes the need for further work to clarify this matter.

Life history and damage. Silvestri (1949) as cited by Tremblay (1991) gives up to 4 or 5 generations per year in Italy. Based on the time it takes for a generation to be completed in summer and autumn, Harpaz and Gerson (1966) estimate at least 6 generations during the insect's occurrence in olive groves, i.e. July to November in Israel. There, the adult female midge appears in the olive groves approximately when oviposition by the olive fruit fly begins. It introduces an egg (more seldom 2 or 3) in the oviposition chamber of the olive fruit fly in the olive mesocarp. The larva hatches within 24 hours. In the fruit fly oviposition chamber where the midge egg was also laid, the *Macrophoma* fungus also develops. The midge larva is mycophagous and saprophagous. As mentioned above, it feeds on the fungal mycelium and on olive mesocarp invaded by the fungus, and possibly contributes to the spread of the fungus in the olive fruit. On Lesbos island, according to Tsirtsis and Tsimbouris (1977), five to six generations are completed per year. Overwintering occurs in the soil, either in the pupal stage (Koronéos 1939, Tsirtsis and Tsimbouris 1977), or as a fully grown larva which is more likely, as suggested by Harpaz and Gerson(1966). On Lesbos, according to Tsirtsis and Tsimbouris (1977), adults of the overwintered generation start coming out of the soil in late March, peak in late April to early May, and continue emerging until early June. The first generation appears in the olive grove in mid-June, and the second one in mid- to late September. From September to mid-November two to three more generations develop. From mid-November onwards, the insect on Lesbos enters the soil and overwinters. Without giving the region or

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their bibliographical source, Coutin and Katlabi (1986) mention that the first adults come out of the soil from late June to early July, and that three to four generations are completed from July to October, with the larvae of the last generation overwintering.

Tremblay (1991) adopts the view of Silvestri (1949) that the midge develops in olives during July-October, but can also develop generations on other plants, including the lentisk, to which it may carry the *Macrophoma* fungus. Harpaz and Gerson in Israel and Tominic (1967a) in Dalmatia did not find this midge on either lentisk, *Pistacia lentiscus,* or on *P. terebinthus.*

The larva, although typically mycophagous, detroys the egg and sometimes kills even the neonate larva of the olive fruit fly, whether sucking their contents or not. This has led certain scientists to consider it entomophagous and a predator of the olive fruit fly and therefore useful. Yet, this midge is certainly not an effective enemy of the fruit fly. On the contrary, the midge, whether through the adult's ovipositor, the egg surface, or the neonate larva, inoculates the fruit fly oviposition chamber, and therefore the olive fruit with the harmful *Macrophoma* fungus (Fig. 309). This is harmful to table olives and, depending on the cultivar, the season of the year, weather conditions and cultural practices, also to cultivars destined for oil production, as the fungus lowers the oil quality. However, the probability of the fungus infecting the fruit through lesions other than those caused by the fruit fly is low in most olive groves.

Another cecidomyid midge, *Asynapta furcifer* Barnes, is often found in olive fruits infested by the olive fruit fly, the *Prolasioptera* midge and invaded by the fungus. According to Harpaz and Gerson (1966), a certain confusion in the field ecology of *Prolasioptera* stems from the external resemblance of its larva to that of *Asynapta*. The larvae of the two species often occur together in olive fruits. Yet, the *Asynapta* larva, which is saprophagous, can easily be distinguished microscopically from that of *Prolasioptera,* according to generic characters.

Control. This midge is reasonably considered harmful because it favors the establishment of the *Macrophoma* fungus to olives. However, its control is indirect, through the control of the olive fruit fly (see below), thus aiming at limiting the sites where the midge can oviposit.

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Resseliella oleisuga **(Targioni-Tozzetti)** ***(****Clinodiplosis oleisuga, Thomasiniana oleisuga)* **(Diptera, Cecidomyiidae)**, comm. **olive bark midge, olive shoots midge**

Adult. According to Coutin and Katlabi (1986), the adult is 2-3 mm long and generally black, except for the abdomen which is orange in the female and greyish in the male. The compound eyes are black or almost black. The antennae have 14 segments and the maxillari palpi 4 articles. Coutin and Katlabi give a picture of the adult.

Egg. It is white, and towards the end of incubation yellowish. Approximate dimensions 0.25-0.30 x 0.05 mm. In groups of several to many on a line, one close to the other, under the bark.

Larva. The young larva is whitish, almost transparent. After the first few days it turns orange-red and finally orange or almost yellow. Fully grown it measures 5 x 2 mm. Arambourg and Elant (1966) give characters and provide drawings of parts of the larval body.

Pupa. The pupa varies from yellow or light brown to orange, and is 1.5 x 2.2 mm long.

Host plants. Most authors consider the olive as the only host, while Coutin and Katlabi (1986) mention that the larvae would be able to live also on some other Oleaceae, namely *Phillyrea* and *Fraxinus.*

Life history and damage. The number of generations completed per year and the seasonal development vary with the region and the authors. In the most recent paper on this insect, Coutin and Katlabi (1986) state that it completes two generations per year in all regions of the Mediterranean where its seasonal history has been precisely determined, except on the northern coast of western Crete where it completes one generation. Bivoltinism is reported by Anagnostopoulos (1939) in Attica, central Greece. On the other hand, Bodenheimer (1930), Arambourg and Elant (1966) and Kotloby (1974) reported one generation in Syria, whereas some other authors suggest three or four per year in other regions. In the regions where the insect is bivoltine, there is a spring and a summer generation, the fully grown larvae of the summer one overwintering in the soil (Coutin and Katlabi 1986). Pupation occurs in late winter and adults appear in spring. They lay their eggs in groups, one next to another, in fissures and other lesions made by other insects, mainly ovipositing homopteran Cicadidae and Jassidae, or physical and mechanical causes (frost, hail, man) in the bark of olive twigs and, less often, of branches. The larvae live side

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by side, with their bodies parallel to one another or almost so, in the cambial region, feeding and destroying the cambium and inner bark. When fully grown, they drop to the ground, where at a small depth they pupate, each in a separate cocoon, or remain dormant depending on the season. The number of eggs laid or larvae observed living together in each gallery (chamber) under the bark vary with the authors from 10 to over 100 (references in Arambourg and Elant 1966) and, among possible other factors, seems to be related to the diameter of the twig. Thus, in coastal Syria, Arambourg and Elant found 9 and 14 larvae in chambers in 4-mm-diam. twigs, and 33 and 67 in 8-mm-diam. twigs.

In Syria, where one generation per year was recorded by Arambourg and Elant (1966), the fully grown larvae do not drop to the soil but remain in the larval chamber under the bark throughout winter, and pupate in situ in March-April. Adults start appearing in late March to early April and freshly-laid eggs are seen in the first half of April. The larvae grow until mid-summer then remain inactive until the end of winter. On the northern coast of western Crete, based on periodical samplings of infested twigs, Argyriou and Marakis (1973) concluded that there is one generation per year. Most of the winter is passed in the fully grown larval stage. Pupae were found from early February to 20 May, adults and eggs from mid-March to late May, young larvae from early April to mid- or late July, and fully-grown larvae from mid-June to late January. Thus, in that region, same as in Syria, there is a period from approximately mid-summer to late winter during which the fully grown larvae remain dormant.

In Tuscany, Bagnoli (1982) made incisions in the bark of olive twigs during the growing season to facilitate oviposition by the midge, and recorded the stages of the insect’s life cycle by periodically sampling twigs. He concluded that, from May to September, there may be 3 or 4 overlapping generations in that area. Certainly specific experimental work is necessary to clarify whether and under what conditions this midge is univoltine, bivoltine, or multivoltine. Koronéos (1939) was not certain that the larvae from central Greece he examined were of the same species as those from Crete.

While infestation usually involves olive twigs of relatively small diameter, there are cases where small branches are also infested. The larval chambers cause withering and ultimate death of the part of the twig or branch distal to them. Therefore, the injury can be of importance in young nursery trees or in newly planted groves where

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the single stem, or a substantial part of the starting branches can be killed. In older trees of fruiting age the percentage of dead twigs resulting from infestation by this midge is generally not such as to cause substantial loss of fruits. According to Bagnoli (1982) the percentage of infested twigs is higher in areas and seasons of frequent rains and hail. Many years ago, the senior author observed in coastal northern Greece, in August, fully grown larvae in twigs of 6-8-year-old olive trees which were next to irrigation sprinklers, while trees of the same grove further away were uninfested.

Control. The main measure to prevent injury is avoidance of wounding the bark. Removal and burning of infested twigs in time, before the larvae abandon them, and removal of the infested part of the bark of branches are measures to reduce the midge population. In unusual cases of heavy infestation, certain authors suggest spraying with an organophosphorous insecticide.

Bactrocera oleae **(Rossi)** *(Dacus oleae, Daculus oleae, Musca oleae)* **(Diptera, Tephritidae)**, comm. **olive fruit fly**

Adult. The general body color varies from light brown to dark brown, while the head is reddish. The body is usually 4-5 mm long. There may be differences in size between populations, as well as between individuals grown under different temperatures and in olives differing in maturity, therefore in nutritional value to the larva. The thorax is darker on the dorsal side, where three longitudinal stripes are discernible (Fig. 310). According to Silvestri (1914), the metanotum is black, the major part of the scutellum and the isopleural spot are yellowish, and there is a big black spot on the metasternum ahead of the base of the legs. The male has a comb of approximately 12 hard setae on each side of the third abdominal tergite. The wings are transparent, iridescent, with a dark spot near the apex. The ovipositor is discernible.

Egg. It is white, long and narrow, slightly curved (banana-shaped), and narrower at the micropyle end. It is inserted in the fruit mesocarp.

Larva. It is whitish or light yellow, 7-8 mm long when fully grown (Fig. 316). The anterior part of its body is narrower than the posterior one. There is no head capsule, same as in all other Tephritidae. In the anterior part of the body the only dark parts are the mouth hooks and the cephalopharyngeal skeleton. There are three larval instars.

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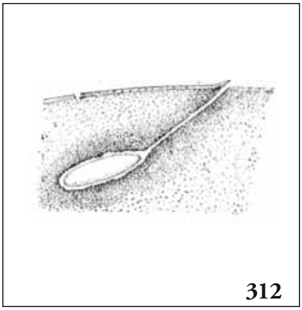
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Figs. 310-322. *Bactrocera oleae.* 310. Adult female (photo D.S. Koveos). 311.A female ovipositing. 312.Section of olive mesocarp (flesh), diagrammatic, showing the slit and terminal little chamber made by the fly's ovipositor to insect the egg (Sta. Firenze). 313. Old oviposition hole (puncture). 314. Gallery of young larva in the mesocarp. 315, 316.Developed larvae (third-instar) in their galleries. 317.Pupa in the larval gallery. 318.Exit hole of adult (right) and to its left a brown "xerovoula" (spot of the fungus *Camarosporium dalmaticum*). 319.A fruit fly control team ready to start work. 320.Bait spraying with a knapsack sprayer. 321.Glass McPhail fruit fly trap for the capture of adult olive fruit flies. 322.Trap man counts the captured flies, after having emptied the trap liquid on the green mesh (photo B.I.K.).

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Pupa. It is ellipsoid, its outer layer consisting of the light brown puparium (sclerotized integument of the fully-grown larva) (Fig. 317).

Host trees. In nature, the fly oviposits and its larva grows only in the mesocarp of fruits of the genus *Olea,* including *O. europaea* (cultivated and wild), *O. verrucosa* (Link) and *O. chrysophylla* (Lam.). Therefore, it is oligophagous, although many authors consider it practically monophagous because it grows on only a few species of *Olea.* All the known cultivars of the cultivated olive can be infested (Neuenschwander et al. 1986).

Life history and damage. The olive fruit fly is among the most important pests of olive. Its geographic distribution is wide, covering the countries bordering the Mediterranean, the Canary Islands, Africa, and from the Middle east to India, as well as more recently North America. It does not occur yet in South America, Australia and central China. In considering the fly's seasonal history, one should remember that the olive fruit is suitable as larval food from early to mid-summer on, depending on the region, and that it ripens over a rather long period, from summer through winter. Also, in certain localities overripe olives remain on the trees long after harvest time, until late spring. Such is the case on Corfu, where fruit is available for oviposition from mid-July until the end of May (Kapatos and Fletcher 1983). In regions with cool and cold winters, overwintering takes place as a pupa in the soil or as an adult in or outside the olive grove. Where winter temperatures allow oviposition and larval growth (coastal southern Greece and certain islands), all pre-imaginal stages may be found on the trees during the winter months, but the egg rarely. The fly is multivoltine throughout its range of distribution. The number of generations per year varies with the region, from two to five. According to P. Katsoyannos (1992a) and references therein, in the northernmost distribution of the species in Europe, such as northern Italy and southern France, where summer temperatures do not exceed threshold values, three generations are reported the most. In southern Italy, Spain, Dalmatia and central Greece, one generation starts in June-July and two more develop in autumn through November or even December, while on the island of Corfu a spring generation on fruits remaining on the trees brings the number to four (McFadden et al. 1977). From July to winter normally two generations are completed in northern Italy around Lake Garda, three in Liguria, and four in Sardinia, while spring generations may

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occur in any area. In western Liguria in summer and autumn four generations are completed near the coast, and three inland. To these should be added one or two in spring, wherever olives remain on the trees (Delrio and Cavalloro 1977). In most areas of Greece, the fly completes 3-4 generations per year. When the olive fruit approaches its final size and becomes soft enough for the fly's ovipositor to pierce it, oviposition starts, usually in July. With its ovipositor the female pierces the epicarp and proceeds in making an oviposition hole in the mesocarp (Fig. 311). This hole is wider at the inner end, thus forming a chamber, in which an egg is laid (Fig. 312). After subtracting its ovipositor, the female regurgitates, on the epicarp around the hole, olive juice that it has sucked up from the hole during the last phase of oviposition. This juice dries out and soon becomes repulsive to ovipositing females. This reduces the probability of more than one egg being laid per fruit. Thus, under a low adult fly population, or when sufficient olives are available, only one egg is laid per fruit, whereas under high fly population density or when fruit are scarce, there may be more than one egg per fruit. The total number of eggs per female is usually a few hundred, while maxima of 700-1200 have been reported. Under optimal conditions flies reared as larvae on olives laid (in the laboratory) 13-40 eggs per female per day, with a maximum of 45-70 eggs, while flies reared as larvae on an artificial diet laid 13-21 per female per day (for references see Tzanakakis 1989). The population of the fly increases especially in autumn, and more so when the autumn weather is humid and relatively warm. The high summer temperatures and low air humidity do not favor this insect.

The adults are long-lived and oviposition by females of the same generation or by different generations continues for weeks or months, until low temperature in late autumn or in winter prevents oviposition. In late summer and early autumn, when fruit is plentiful and activity levels high, adults live probably no longer than 6-8 weeks (Fletcher 1989a). However, adults of autumn generations and especially those emerging in late autumn, can survive the winter and spring, and infest the next season's crop in early summer (Arambourg and Pralavorio 1970). The adults of both sexes can successfully withstant the winter temperatures of the regions where they occur. For survival and/or reproduction, the adult flies need to frequently feed on various organic substances, liquid or solid, such as insect honeydews, flower nectar, other plant exudates, pollens, juices, and tissues of damaged

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or decaying fruit (see Tsitsipis 1989, Tzanakakis 1989 and references therein). These substances the adult finds not only on olive trees, but also on other plants near or far from olive groves. In addition, bird dung, insect excreta, and plant surface bacteria and yeasts are likely to also be fed on, as observed in some other species of fruit flies (Drew et al. 1983, Prokopy and Roitberg 1984).

The larva bores a gallery in the fruit mesocarp (Figs. 314, 315, 316) which mesocarp it macerates before ingesting it. When fully grown, it extends its tunnel to the epicarp and pupates in the fruit (Fig. 317), or drops to the soil. In summer it pupates usually in the fruit, while in autumn and winter usually in the soil at a small depth. It seems that the riper the fruit and, hence, the softer and more juicy and oily the mesocarp, the more likely the larva is to abandon it and pupate in the soil. Under optimal conditions the life cycle can be completed in a little over a month. When the olive is green (not fully ripe), the larva needs the presence of extracellular symbiotic bacteria in its digestive tract to be able to utilize the olive mesocarp and survive. These bacteria are on the inner surface of the female's ovipositor, and during oviposition are smeared over the surface of the egg. From there they enter the digestive tract of the neonate larva. A number of investigators have isolated bacteria from the digestive system of the fly, in an effort to identify the symbiotic one(s) (for earlier references see Tzanakakis 2006). Using a molecular method, Capuzzo et al. (2005) detected and propose as a symbiotic bacterium a new one: *Erwinia dacicola.* Kounatidis et al. (2009) found *Acetobacter tropicalis* to be predominant among the several bacterial taxa they detected. This bacterium was detected in both laboratory stock and field-collected flies from different localities of Greece, and is capable of colonizing and lodging in the digestive system of both larvae and adults, as well as in the Malpighian tubes of adult flies. Whether the fly larva needs the symbiotic bacteria only to be able to utilize the olive mesocarp or also to obtain additional nitrogen or carbohydrates, as found in the Mediterranean fruit fly (see review by Behar et al. 2009), remains to be seen. The oviposition hole of the fly, commonly known as "puncture" (Fig. 313) helps the entrance and settling of the fungus *Camarosporium dalmaticum* Berl. & Vogl., also known as *Sphaeropsis* or *Macrophoma dalmatica.* This fungus causes the necrotic spot "xerovoula" in green olives and the "sapovoula" in ripe olives (Figs. 318, 309). The fungus can enter the olive fruit also from other wounds. However, the olive fruit fly's puncture is

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the most common point of entrance of the fungus. The olive fruit midge, *Prolasioptera berlesiana* (see above), often oviposits in the fly's oviposition hole. This facilitates the spread of the fungus in the fruit. According to certain scientists the midge is likely to carry the fungus, thus increasing the probability of inocculation of the olive fruit. Except on olives, the larvae can be reared also on a number of artificial diets (Tzanakakis and Economopoulos 1967, Tsitsipis 1983, Tzanakakis 1971, 1989). For the larva's nutritional requirements see Tsitsipis (1989). Mass rearing on an artificial diet is necessary when the sterile insect release method of control is applied (see below).

Adults of both sexes are attracted to traps containing various ammonium salts as such, or as solutions in water, as well as to solutions or suspensions of protein hydrolyzates. In addition to releasing ammonia, the amino acids in the protein hydrolyzates act as feeding stimulants. This makes them effective components of bait sprays (Roessler 1989). The responses of fruit flies, including *B. oleae,* to objects of various color, shape and size have been reviewed by B. Katsoyannos (1989), and the use of traps based on color and/or shape by Economopoulos (1989). Effective traps based on such knowledge have been developed for either adult population monitoring, or mass trapping of the fly (see below). The adults also respond to pheromones emitted by the other sex. Sexually mature males release a pheromone during the hours of sexual activity. This odor is easily detectable by humans (Economopoulos et al. 1971). The females release a pheromone which acts as a male attractant. It is a blend of four compounds. For details and references see Mazomenos (1989), and Haniotakis (2000). The synthetic major component of the blend has been used, together with a food attractant in traps.

Bactrocera oleae is the most serious insect pest of olive in Greece and in some other Mediterranean countries. Certain authors consider it as the most harmful insect to Greek agriculture. It has been studied more than any other insect in Greece. For a recent review of the respective literature, in Greek, see Broumas (1994, 1995) and Ziogas (1996). The Greek state has been spending for years substantial sums of money for the control of this insect, and for research aiming at improving the methods of its control.

Control. In Greece, sprayings with insecticides alone or in combination with attractants, and mass trapping of the flies have long been applied with success by both state services and individual olive growers. Also, biological methods have been tested, such as the

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introduction and release of natural enemies of the fly (entomophagous insects), mass releases of flies sterilized by irradiation and combination of some of these methods, in an effort to achieve integrated control of the fly and of other pests of the olive tree.

Cover sprays. This method can be applied from the ground or the air. Applications from the air were made mainly by state agencies or under the coordination and supervision of state agencies. Today spraying by air is prohibited by European legislation, therefore, spaying is applied only from the ground, mostly by individual growers and pest control operators when absolutely necessary. The whole tree foliage is fully covered with the spray liquid, to kill the adult flies present in the grove as well as those that will come in contact with the foliage in the coming days or few weeks. When using certain organophosphorous insecticides that penetrate to somne extent the fruit, killing of the larvae of certain age inside the fruit is also possible. Cover sprays have been known as a curative or therapeutic method of fly control. Spraying is done with high-volume sprayers, to run-off (10-25 liters of liquid per tree of average size) or, less often, with back-on low-volume sprayers (1-1.5 liters per tree). Spraying is applied when the percentage of “fertile infestation” (eggs, plus live larvae, plus pupae, plus larval galleries) reaches 5% of oil-destined olives, or 2% of table olives (Ziogas 1996). Other sources recommend as intervention density 2-4% fertile infestation for oil-destined olives, and a much lower percentage for table olives (Broumas 1994). In many areas 2 to 4 curative sprays are needed for the protection of the olive crop. The officially established periods from last spray to harvest should be meticulously adhered to, so that the olive oil contains no unacceptable insecticide residues. Such residues are practically not reduced with time in the olive oil. Cover sprays result in the death of many useful entomophagous insects, to a much greater extent than the other methods of control. A frequent consequence of the elimination or much reduction of those entomophagous organisms is the build up of harmful populations of scale insects and other enemies of the olive tree. Therefore, cover sprays should not be recommended except in cases where other methods are unlikely to be effective because of sudden high percentage of fruit infestation, as well as in a number of table olive cultivars where the percentage of acceptable fruit infestation is virtually zero.

The possible development of resistance to the insecticides used year after year against the fly in extended areas, has long been of

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concern to the scientists and authorities involved. Chrisargiris et al. (2011) have sampled field populations of the fly from various areas of Greece where distinct fly control programs have been applied. They found resistance to be under control over the last years. Furthermore, a reduction of resistance to dimethoate was recorded, possibly because of proper alternation of different insecticides in the fly control programs. The most striking resistance phenotypes and the highest frequencies of resistance markers were observed on the island of Crete. Resistance mechanisms against pyrethroids and spinosad are being analyzed, to develop molecular diagnostic tools for early detection and management of olive fruit fly resistance.

Bait sprays consist of a mixture of an insecticide with a food or a sex attractant, which is sprayed on the foliage of the tree. Flies of both sexes are attracted to the sprayed foliage and killed by the insecticide. The purpose is to kill the flies before they oviposit in the fruit. Therefore, bait sprays are considered a preventive method of control. The insecticide is usually an organophosphorous, a synthetic pyrethroid, or other, depending on the existing regulations of the particular country, the recommended dose per tree or hectar, and the season. The food attractant is a low-cost protein hydrolyzate, an ammonia releasing salt, or urea. The sex attractant is usually 1.7 dioxaspiro (5.5) undecane. The flies feed on the baits containing protein hytdrolyzates. This enhanses the killing rate. However, the flies do not feed on baits containing ammonia-releasing salts (Haniotakis 2005). This is why in the latter case molasses are added to salt preparations to encourage feeding. Baits from the ground are sprayed either with knapsack sprayers (Fig. 320), or more often with high-pressure tractor-mounted sprayers. Spot spraying of one every 2, 3, or even 4 rows of trees is desired, depending on the case. However, in actual practice, a large portion of the tree is sprayed as tractors move through the grove, and most Greek olive growers insist on spraying all trees of the grove, claiming that the efficacy is not sufficient otherwise (Haniotakis 2005). Bait sprays, when properly and timely applied, are effective and constitute the current standard method of olive fruit fly control (Haniotakis 2005). Yet, as any control method, besides advantages, bait sprays have also drawbacks. They cause a quick decline of the fly population, but there is often a quick recovery, requiring repetition of the bait spray. Repeated applications are needed in as large an area as possible. Among the factors and conditions to consider to properly time each spray are: fly population density as determined with traps,

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reproductive maturity of the trapped females, fruit maturity, cultivar, fruit load of the trees and time of the year (for more on this matter see Haniotakis 2005, and visit the sites http://www.oliveoilnews.com/olive fly.htm, and http://www.oliveoilsource.com/olive fly.htm).

The carrying out of bait sprays is supervised by the Olive Protection Services, which are state services under the local Directorates of Agricultural Development, or the Directorates of the Ministry of Agriculture. The sprays are carried out in an area, only if the percentage of fruit set at the beginning of the olive-growing season exceeds 25% of a full yield for oil-destined cultivars, or 20% for table-olive cultivars. To carry out the work of "dacoctony", as are commonly known the state measures of controlling the fly, seasonal staff is hired. A wider olive-growing area within a prefecture is divided into "sectors". Every sector covers approximately 250000-300000 olive trees, and is subdivided into smaller units. Each sector is supervised by an agronomist, the "dacoctony sector head". In the subdivisions of each sector "dacoctony teams" are formed from specifically-hired staff (workers) living in the respective area. A team (Fig. 319) is composed of the chief-worker, transporters (with mules or motor transportation means), the spraying staff, and the trap-setter.

The sprayers that are used in bait sprays that are carried out from the ground, have nozzles without needles (Fig. 320), so that the drops emitted are not fine. The spray liquid contains the proper concentration of the insecticide and 2% of a protein hydrolyzate or other product with a similar attractive action. A number of protein hydrolyzates are available on the market. In case of high fly population density the attractant concentration is raised to 3%. When there is a normal density of trees in the grove, only part of the canopy of every third tree is sprayed, in the form of large drops and at approximately 300 ml of spray per tree.

The first bait spray of the year, if considered necessary, is carried out from mid-June to early July. It should be general (cover the whole area) and be completed within 7 to 10 days. To determine its necessity and the proper time to apply it, certain criteria are considered. Among them are the density of the adult fly population, the sex ratio (desired approximately 1:1 males to females), the presence of mature oocytes in more than 5% of the captured females, the suitability of the fruit for oviposition (hardness of the endocarp) and weather conditions favoring the fly's reproductive maturation and oviposition.

To follow the progress of the adult population, glass or plastic

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McPhail fly traps (Fig. 321) have been used in Greece during the last several decades. They contain, as attractant, a water solution of 2% ammonium phosphate or ammonium sulfate, and in some experimental cases a water solution of 4% protein hydrolyzate plus 1.5% borax. Teams of specially-trained "trapsetters" undertake the placement and servicing of the traps. Fifty traps are surviced by each team of trapsetters, using approximately one trap per 1000 trees. Checking of the traps and renewing the attractive liquid are done every 5 days. The captured flies of each sex are counted (Fig. 322), and the presence of mature oocytes in the females recorded in the laboratory. Spraying is recommended when 5-20 flies are caught per trap per 5 days, depending on the olive cultivar and on the percentage of fruit-bearing of the trees (percentage of a full olive crop). Except for the first spray which is general over a large acreage (often on a whole prefecture), additional general or localized sprays can be carried out. To determine the need for them, in addition to trap captures, the percentage of fruit infestation is determined by regular fruit samplings. The last spray should be done at least 2 to 4 weeks before the beginning of harvest, depending on the insecticide used. To minimize undesirable insecticide residues in the oil, the insecticide of the last spray should be of low mamalian toxicity, or be sufficiently water-soluble so that a high proportion of it is discarded with the water phase of the olive slurry in the oil factory.

Mass trapping. It is based on the same principle as bait sprays, i.e. to attract and kill as much of the adult population as possible. The traps have less adverse effects on those beneficial organisms walking or settling on the foliage but not attracted by the trap attractants. Also, they have a longer period of attractancy to the flies than bait sprays have. Of the various traps available, only two had been registered by 2003 (Haniotakis 2003). One of them consists of a hardboard envelope which contains ammonium bicarbonate which in contact with air releases the fly's food attractant ammonia. The outside is impregnated with a proper insecticide of long residual action, and also holds a dispenser with the major component of the fly's attractive sex pheromone. The effective life of some of those registered traps is 6 months, covering the entire period of fly reproduction and fruit susceptibility in certain areas. For details concerning the mass trapping of the fly, see among others Broumas and Haniotakis (1987), Broumas et al. (1983, 1985, 2002), Economopoulos et al. (1986), Haniotakis (1991, 2003), Haniotakis et al. (1986, 1991), Zervas (1986).

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For a review in Greek of the respective literature on non chemical methods of controlling the fly, see Broumas (1995) and Haniotakis and Ziogas (1996).

Compared to bait sprays, traps have a slower attract and kill rate of the fly population, therefore, they must be installed in summer 10 days before the beginning of fly oviposition and fruit susceptibility to oviposition. Yet, mass trapping has a gradual, longer and steadier effect than a bait spray, and is the method of choice when fly population densities are low. After 3 consecutive years of mass trapping in central Greece, the fly population was kept below the economic injury level (Broumas et al. 2002). During the first 2 to 3 years, one trap per tree may often be needed for acceptable protection of the crop, whereas in periods and localities favoring the build up of high populations, complimentary bait sprays may be needed. As a rule, a combination of bait sprays with mass trapping gives a better protection of the crop than either method alone.

If properly prepared and used, bait sprays and mass trapping have minimal adverse effects on the ecosystem and especially on the useful fauna of olive groves. Therefore, they are fully compatible with integrated control. For techniques to sample fly populations and certain other major pests of olive, see Kapatos and Stratopoulou (1984).

Other methods. Biological control of the fly in Europe by introduction of the parasitoid *Opius concolor* Szepl. in areas where it did not occur, or with mass releases of it, did not give encouraging results and was not continued. Mass releases of radiation-sterilized flies, in combination with bait sprays in coastal Halkidiki, kept the fly population to low levels (Economopoulos et al. 1977), but technical requirements and other reasons did not favor the testing in larger areas, and this effort was not continued. Recently, an interest has been shown to try this method again, after improving the quality of the flies to be released, learning certain critical aspects of the basic biology of the fly, and improving rearing conditions and facilities (see review by Estes et al. 2012). Daane and Johnson (2010) summarized the methods used in controlling the fly and pointed out the increasing evidence that field populations have the potential to develop substantial resistance to commonly used insecticides against them (see also Chrisargiris et al. (2011) and references therein). Therefore, noninsecticidal methods of control should be developed,

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so as to reduce the selection pressure of insecticides on resistant fly populations. Daane and Johnson (2010) enumerate noninsecticidal methods that have worked in some cases or have shown potential to deserve further examination. Their review covers especially fruit fly parasitoids, and suggests those worth of further study with the purpose of using them in integrated control programs in olive groves. Yet, until such valuable research leads to noninsecticidal methods effective over large areas, olive fruit fly control in Greece and many other countries of the Mediterranean Basin has to rely on one or more of the three methods briefly described above, i.e. bait sprays, cover sprays and mass trapping.

***Parectopa latifoliella* Millière** *(Ecophyllembius neglectus* Silvestri) **(Lepidoptera, Gracillariidae)**

Adult. The adult moth is 4.8-5 mm long. The head and forewings are dark grey, the latter with metallic reflections, and three small whitish spots near their inner margin (Silvestri 1943).

Larva. There are three larval instars. The penultimate (second-instar) larva is 6 mm long, while the last one slightly shorter, 5.6 mm. It is a leaf-miner. The last (third) instar does not bore the leaf further, but only spins the cocoon in which to pupate. Silvestri (1943) provides nice drawings of the adult and of the larval gallery in olive leaves.

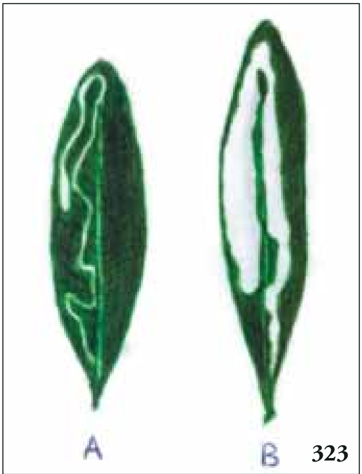

Fig. 323. *Parectopa latifoliella.* Typical galleries in olive leaves (Redrawn from Silvetri 1943).

Host plants. Olive, oleaster, *Phillyrea latifolia* and *P. angustifolia* (Balachowsky and Mesnil 1935, Silvestri 1943).

Life history and damage. According to Silvestri (1908, 1912b, 1943), it is bivoltine and overwinters as a larva in its gallery in the leaf, where it also pupates. The instar in which the larvae overwinter is not specified. Adults of the overwintered, second,

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generation are formed in spring to early summer. In the Naples area of southern Italy, the adults appear mostly in the second half of April and in early May, whereas in the cooler region of Umbria a month later. The eggs are laid singly on leaves, mostly on the upper leaf surface, and preferably on the basal third of the leaf. The larva bores a characteristic long gallery (Fig. 323) and pupates near the end of it. To complete its growth the larva in spring requires 40-60 days. In Naples, adults of the first generation appear mostly in July. From Silvestri's data, we must assume that hatching of the larvae of the second generation occurs mostly in August. The larvae of this, second, generation are also leaf miners, and overwinter. Arambourg (1986b) suggests that a third generation may develop in southern Italy, but gives no supporting data. *P. latifoliella* causes no economic damage to olive. Effective natural enemies keep its population density low.

***Zeuzera pyrina* L. (Lepidoptera, Cossidae)**, comm. **leopard moth, zevzera**

This moth has long been known as an important pest of pome trees in many countries. For data on morphology, host trees, life history and control of this polyphagous moth on pome trees, see the respective chapter. Below only data concerning the olive tree are given. This part should be considered in conjunction with that concerning pome trees. *Zeuzera pyrina* (Figs. 108-110) is known as a pest of olive only in some relatively warm regions of its range, such as warm parts of southern continental Italy, but not Sicily, Greek islands of the eastern Aegean, and other eastern Mediterranean countries, from Turkey to Israel and Jordan (Martelli 1961, Swirski 1985, Nakache 1986). Why this moth infests preferably olive in some warm regions and Rosaceae in most other regions is not clear. Some eastern Mediterranean populations may be genetically different from those of other regions. The matter deserves investigation.

Host plants. Among its many host plants are the olive, *Fraxinus* and *Syringa.*

Life history and damage. On olive, this moth is reported from partivoltine to univoltine, depending on the region. In Israel the life cycle is completed in 1 year (Lisser 1951 cited by Moore and Navon 1966, Avidov and Harpaz 1969), in low altitudes of Lebanon and Syria in 1 year, and in high altitudes of those two countries in 2

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years (Talhouk 1969). In southern Europe and particularly in the zone where olive is grown there is 1 generation per year. Data on seasonal history on olive are limited, with most authors describing the cycle occurring on pear and apple. Overwintering on olive seems to take place as a fully grown larva in its gallery in the tree. According to Silvestri (1943), in the Brindisi and Lecce provinces of southern Italy, pupae in olive trees were found from July to September, and mated adult females a little later. In Israel, adult emergence from olive trees was late, from August onwards (Yathom and Rivnay 1967). On Samos island of the eastern Aegean Sea, Koutroumpas (1981) reported univoltinism, with adults emerging from mid-July to early October. In the Giza area of Egypt the adults emerged from late April to mid-November, with peaks in late May, mid-August and mid-September. In the Fayoum area of that country adults emerged from mid-April to late November, with peaks in late September and mid-October (Ismail et al. 1992). According to Nakache (1986), the female lays up to 2000 eggs, of which many hundreds may be laid on a single site. The neonate larvae first weave a nest where they remain together for one or more days. Subsequently they disperse quickly and move towards the tips of young shoots where each enters and bores a subcortical gallery. In southern Italy, according to Silvestri (1943), the larva bores a gallery in olive twigs which are 1-3 cm in diameter. This gallery is longitudinal, in the outer wood, without reaching the center of the twig, and 3-8 mm wide. According to Avidov and Harpaz (1969), in olive trees many galleries slant both upwards and downwards, or follow a circular course, while others ramify like the boughs of a tree. As the young larva develops, it may abandon the first shoot or twig and enter a second one. When it is 3 to 6 weeks old, it infests 1- to 4-year-old twigs or small branches. Later it enters larger branches or the trunk. In branches the gallery is in the cambial region and can reach 25-50 cm. Therefore, during its development the larva moves progressively from the youngest shoots to large branches and then to the trunk (Nakache 1986). In olive, the galleries in the trunk are close to ground level and lead down to the root collar and the roots. Pupation occurs in the larval gallery.

Wherever and whenever it occurs on olive, the leopard moth may cause considerable damage to this tree. The galleries in twigs, branches and trunk result in substantial reduction of production and ultimately in the death of the tree. In Israel, it is a serious pest of olive and to a lesser extent of other fruit trees (Swirski 1976, Nakache

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1986), and populations became denser after the introduction of new olive cultivars in that country (Yathom and Rivnay 1967). In Egypt it is also an important pest of olive (Ismail et al. 1992). According to Avidov and Harpaz (1969), olive branches 5 cm thick will die if they contain 7 or more larval galleries. In olive trees where the insect has not been controlled, the number of galleries may reach more than 50. European cultivars are infested more than local cultivars in Israel. Without specifying the country, Nakache (1986) states that in developed trees, galleries in 1- to 2-year-old shoots do not cause serious damage, because new cambium is formed in the young galleries which strengthens and regenerates the young twigs, depending on the physiological state of the tree and the cultivar. However, young 1- to 2-year-old trees are killed even if a single larva enters their trunk. In trees 3 to 5 years old or more, part of the canopy may be killed. Trees of middle age (5 to 20 years old) are infested less, but 25- to 50-year-old trees experience heavy damage. Infested branches dry and break, especially in years of heavy crop.

Control is difficult because of the rather long periods of adult emergence and of oviposition. Sex pheromone traps are used to monitor the adult populations and time insecticidal applications. Larger larvae are killed mechanically by inserting a wire into each gallery. In addition, special gas-emitting wicks are inserted, or a proper insecticide is injected in the galleries and the entrance plugged. In Italy satisfactory control has been achieved on apple and pear trees by introducing ear wicks soaked in a water suspension of the entomopathogenic nematode *Steinernema carpocapsae* Weiser into the larval galleries (Deseö 1982). There is no information on such an application to olive trees.

Another species of the same family, *Cossus cossus* L. (Figs. 106, 107), is a polyphagous large-size bark and wood borer of broad-leaved trees. Its morpholoy and life history are given briefly in the chapter on insects of pome trees. In Greece, and more often on islands of the eastern Aegean, it also infests and damages olive trees. It often co-exists with *Z. pyrina*. On deciduous trees it completes one generation in 2 or 3 years (Balachowsky 1966a). Without giving experimental data, Sarakomenos (1920) mentions that on olive on Corfu, the young larvae hatch in July-August and take 3 years to become fully grown.

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***Prays oleae* (Bernard) Lesne** *(P. oleellus)* **(Lepidoptera, Yponomeutidae)**, comm. **olive moth**

Adult. It is 6-6.5 x 1.6 mm and has a wing span of 13-15 mm and antennae half as long as the body. Its general color is grey to greyish white, or light brown, with variations in general body color being observed between generations. There is a black spot at the apex of the mesoscutellum. The eyes are dark brown. The forewings have metallic reflections and scattered dark-brown to black lines, spots, and scales (Fig. 324). The hind wings are uniformly light grey without dark points or spots (Silvestri 1942, Pelekassis 1962b).

Egg. Seen from above it is almost circular, approximately 0.5 x 0.4 mm, white to light yellow. It is flat like a plano-convex lens.

Larva. It is brownish green, greyish green or greenish grey, with brown head and prothoracic shield. (Figs. 330, 332) There are 5 larval instars. According to Silvestri (1942) the first-instar larva is hazelnut colored, with brown head and anal shield, and light brown prothoracic shield. The fully grown last-instar larva is hazelnut brown or darker brown, with the head dark brown to almost black, or with the posterior head black. It has two longitudinal dorsal sublateral stripes which are olive-green or dark green, and two narrower longitudinal subspiracular stripes pale brown, and measures 7-8 x 1.4 mm. In some instars and conditions, there are two dark spots on the prothoracic shield (Fig. 332). In flower-grown larvae the color is less intense than in leaf-grown ones. For details in external structure of adults and larvae see such publications as Silvestri (1942), Pelekassis (1962b), and references therein.

Pupa. Brown, 5-6 mm long, in a loose cocoon, usually in protected sites on the tree or the soil.

Host trees. This insect can be considered oligophagous or even monophagous (Sacantanis 1955), because it is known to complete its life cycle on only the olive and the oleaster. It is reported as also infesting a few other Oleaceae of the genera *Phillyrea, Jasminum* and *Ligustrum,* however, in nature, larvae have been observed only on *Phillyrea angustifolia* and *P. latifolia* (Hering 1957, Arambourg 1966, Arambourg and Pralavorio 1986), and there is no evidence that all its three annual generations can be completed on these two plants. In several regions of the Mediterranean and of the Middle East it is considered one of the major pests of the olive tree. The larvae feed on different parts of the tree, depending on the generation.

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Life history and damage. As given by Silvestri (1907, 1943), and subsequent authors as Melis (1946), Sacantanis (1955), Tominic (1958), Pelekassis (1962b), Arambourg (1964, 1966), Ramos et al. (1977), and references therein, the seasonal history of this moth is as follows: Throughout its range of distribution it is trivoltine, the eggs of each generation being laid and the larvae feeding, as a rule, on different parts of the olive tree, namely flowers, fruits, and leaves (Silvestri 1943). The winter is passed in the larval gallery in the leaf (Figs. 326, 327). There is slow larval growth in winter. In late winter to early spring the last-instar larva abandons its gallery in the leaf to feed externally on leaves of the previous year (Figs. 325, 328) but also on axillary buds and tender leaves and shoot tips of the new growth. The adults of the overwintered (phyllophagous) generation appear in spring, when the inflorescences of the olive tree are at a certain stage of development, well before bloom. Depending on the region and year, these adults appear in late March in Tunisia, in March-April in Morocco and Lebanon, in April-May in southern France, Italy and Greece, and in May-June in Andalousia, Spain (Silvestri 1907, Anagnostopoulos 1939, Pelekassis 1962b, Arambourg 1966, Mechelany 1969, Arambourg and Pralavorio 1986). The number of eggs laid by a female does not seem to exceed a few hundred. The eggs of the first generation, known as the anthophagous one, are laid singly on the calyx and, less often, at the base of the still closed corolla. The larva bores through the egg shell directly into the closed flower, feeding mostly on the anthers and the pistil. Subsequently it enters consecutively neighboring flowers which it likewise erodes. One larva usually erodes 3 or more, and up to 20, flowers which it unites with silk threads, before attaining full growth, in approximately a month. When it has completed gowth, it pupates in a loose cocoon in an inflorescence, between infested flowers, or in near by other suitable sites. Pupation occurs in late May, when the olive trees are in full bloom. The adults of this generation appear from May to July, but in most regions in June, when the young fruits have formed. They lay the eggs of the second, or carpophagous generation, preferably on the calyx of the young small fruits (Fig. 329), but also on the epicarp. According to certain authors, the females select for oviposition small fruits, not larger than 4 mm. The young larva bores directly into the fruit and through the mesocarp reaches the inner part of the still soft endocarp. There it bores a sinuous gallery in the inner part of the endocarp and in the testa (seed coat). When the young larva enters the

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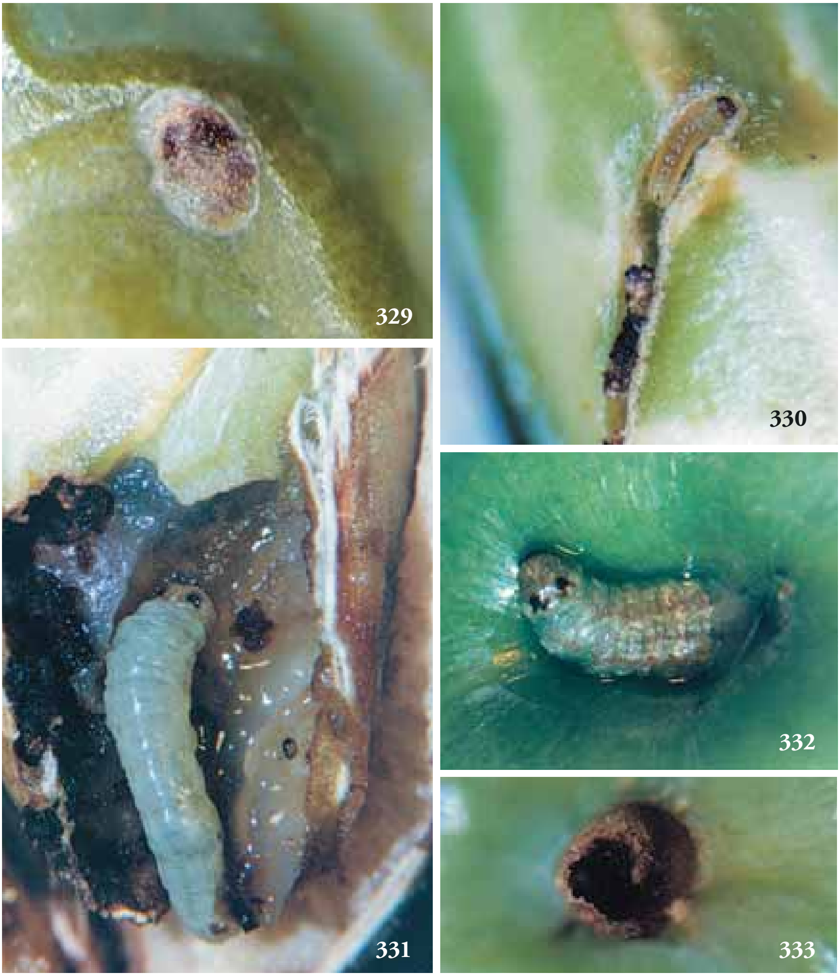

Figs. 324-333. *Prays oleae.* 324.Adult (photo A. Hatzigeorghiou). 325.Two larvae of the phyllophagous generation. 326.Galleries of larvae of first-instar (fine serpentine part), and second-instar (wider part). 327.Galleries of third-instar larvae. 328.External erosion of leaves by fourth- or fifth-instar larvae (photo N.A. Kouloussis). 329.Egg shell on the calyx of an olive fruitlet after eclosion of the larva. Evident are the dark feces of the larva which entered directly into the fruitlet. 330. Second-instar larva and its gallery in the surface layer of the seed. 331.Fourth-instar larva and erosion of the seed. 332.Fully grown larva (fifth-instar) abandoning the fruit. 333.Exit hole of larva at the base of an olive (photo A. Hatzigeorghiou).

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fruitlet to reach the endocarp, it severs the pedicel or the fibrovascular ducts at the basal part of the newly formed fruit, causing it to darken, dry, and fall. The dried fruitlet looks like a dry pepper seed, the Greek olive growers calling it “pepper”. Later, in those infested fruits that do not fall, the larvae develop normally. The larval gallery can injure the olive fruit also later, when it is 8 mm long or longer. Then again it shrinks, blackens and usually drops. This fruit the growers of certain areas call it “kalogri”. During its first stadium the larva is reported to feed little and grow slowly. Later, when the olive embryo is formed and becomes solid, the larva consumes it completely or almost so (Figs. 330, 331), and grows fast. Thus, the larva of the carpophagous generation grows first as a fruit borer, then as a seed feeder. The larval stage of this generation lasts approximately 3-4 months, i.e. much longer than that of the previous (anthophagous) generation. After completing its growth (Fig. 332), the larva opens an exit tunnel (Fig. 333). This tunnel is made at the basal part of the endocarp and, through the mesocarp, is directed towards the pedicel. This exit tunnel also severs the fibrovascular ducts of the base of the fruit, causing the fruit to fall, usually in September-October (P. Katsoyannos 1992a and references therein). Pupation takes place in a loose cocoon on the underside of a leaf, or between leaves that the larva connects with silk threads. However, the larva may pupate also at an other neaby suitable site on the tree. A substantial percentage of the infested fruits drops before the larvae abandon them. In such a case pupation occurs in the soil. The adults of this second generation emerge mostly in September-October and in some groves until late November (Arambourg and Pralavorio 1986), and lay the eggs of the third, phyllophagous, generation singly on the leaves. The first-instar larva of the phyllophagous generation bores a long serpentine gallery in the leaf (Fig. 326), where it spends the autumn and early winter, then molts and continues its slow growth as a leaf-miner in winter and subsequently as an external foliage feeder in late winter to early spring. In Spain, the larval stage of this generation lasted on average 214 days, as compared to 42 for the anthophagous generation and 109 days for the carpophagous one (Ramos et al. 1977). Therefore, the larva of the olive moth lives as leaf-miner and leaf-eater, as flower-borer and flower-eater, and as fruit-borer and seed-eater. When the trees have no flowers or fruits, the eggs of both the anthophagous and the carpophagous generations are laid on leaves. Under such exceptional field conditions, all three generations can be completed

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on leaves (Silvestri 1943).

In addition to factors causing mortality to other insect species, the larval population of the carpophagous generation is subject to mortality because of the physiological fruit drop which occurs in early to mid-summer, and of the drop during the same season caused by the larva itself. In either case, the larvae cannot complete growth and perish in the dropped fruits that dry out (Fournier et al. 1980). Mortality due to early fruit drop can often be high.

The virgin adult female releases a sex pheromone which attracts males. Its major component, Z-7 tetradecen-1-al, has been used in traps to monitor male adult populations and determine when to apply control measures.

The injury to ripe leaves in winter and to buds, young shoots and leaves in early spring, is not usually important. There are, however, a few cases where in young olive trees destruction of the apical part of a shoot may be of importance and justify control measures. The injury to flowers by the anthophagous larvae is also usually considered of little economic importance, because in years of abundant or medium flowering, only a small percentage of the flowers bound to give fruits is destroyed. It is generally accepted that under normal or abundant flowering, 4-5% of flowers give sufficient fruit for a good crop (Alexandrakis and Bénassy 1982). Consequently, in years of normal flowering, even a dense larval population leaves uninfested the small percentage of flowers necessary for a satisfactory yield. Therefore, insecticide applications against the anthophagous generation are necessary only in exceptional circumstances of very poor flowering, coinciding with a dense moth population. By contrast, it is damage to the fruits by larvae of the next, carpophagous, generation that may be serious. It is this damage to the fruit that rates the olive moth as one of the major insect pests of the olive tree. Fruit damage consists in the drop, in early to mid-autumn, of grown but still unripe olives soon after the grown larvae abandon them. The extent of such fruit drop depends on the percentage of oviposited fruitlets in summer. In addition, there is an early summer drop of oviposited fruitlets (Polyrakis 1996, Hadzigeorgiou and Prophetou-Athanasiadou 1997, Paraskakis 1997). This early drop is overlooked by many growers, although in certain cultivars it may constitute a higher percentage of crop loss than the autumn drop.

In Portugal, a three-year study showed a significant linear relationship between accumulated male moth captures in Delta

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pheromone traps and the percentage of infestation of the flowers and fruit by the larvae of the respective generations (Bento et al. 1966).

The olive moth has many natural enemies: predatory Diptera, Lepidoptera, and Neuroptera, and many parasitic Hymenoptera and a few Diptera. Of those enemies more important are *Ageniaspis fuscicollis* Dalm. var. *praysincola* Silv., *Chelonus eleaphilus* Silv., and *Trichogramma* sp. Yet, they are not able to reduce the moth populations to tolerable levels.

Control. As a rule, control is chemical. Most scientists that have dealt with the control of this moth, recommend, when necessary, one or two insecticidal applications against the young larvae of the carpophagous generation. These applications are carried out usually in early to mid-June. They aim at killing the embryons inside the egg shell, or the neonate larvae when they are penetrating the fruitlets, or shortly after they have penetrated. If the insecticide is of medium or long residual action, only one application usually suffices. The proper time of application is determined either by date, or on the basis of fruit phenology. The trees are sprayed carefully when the young olives have the size of a kernel of wheat, i.e. 4-5 mm (Arambourg and Pralavorio 1986). For trees of the large-fruit Greek cultivar Konservolia on the island of Euboea, Pelekassis (1962b) recommends 8-15 June, when the fruits there are 7-10 x 6-8 mm. The optimum size of the fruits to spray depends on the cultivar, yet, when the fruits surpass 9 mm, the effectiveness of organophosphorous insecticides is reduced. Monitoring of the adult moth population is done by placing sex pheromone traps in the grove, which catch adult males. Experiments in certain areas of northern Greece and of Crete have shown that hatching of young larvae follows by 12-14 days the capture of adult males in pheromone traps (Polyrakis 1983, Kyparissoudas 1987, Kyparissoudas and Broumas 1990). We can ascertain hatching by examining a relatively small number of fruits and spray in time to kill the young larvae. When the insecticide we have selected does not have a long residual action, and we see that the presence of adult population and oviposition in the grove are extended, we may need a second spray. This second spray is done 2-3 weeks after the first.

Usually systemic and contact insecticides, as well as insect growth regulators (IGRs) are recommended. IGRs are more selective than the organophosphorous and carbamate insecticides, however, they should also be applied in time, i.e. at the start of the oviposition period. The spray is recommended to be done 5-7 days after the

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beginning of adult moth captures in pheromone traps (Kyparissoudas and Broumas 1990). Perdikis et al. (2013), in a certain grove and year in Crete, had a very low fruit infestation despite the high number of moths caught in pheromone traps. They suggest that the infestation of fruitlets should also be counted in addition to pheromone trap captures for the appropriate management of the moth.

Sprays against young larvae of the anthophagous (first) generation are done only in cases of poor flowering combined with high moth population density. In such cases an insecticide is applied shortly before full bloom, when 3-5% of the flowers has opened. Organophosphorous insecticides or formulations of *Bacillus thuringiensis* are suitable (P. Katsoyannos 1992a and references therein). Formulations of *B.t*. do not kill useful insects and other arthropods in the grove, and are safer for man and the environment.

Mating disruption has also been tried in Italy by dispersing sex pheromone-releasing rubber septa (Delrio 1985 and references therein).

In Erythraea, larvae of *Prays chrysophyllae* Silvestri were observed in September injuring flowers of *Olea chrysophylla,* in a way similar to that *P. oleae* injures flowers of *O. europaea* (Silvestri 1943). The inflorescences of the olive tree are also infested by larvae of two polyphagous Lepidoptera, the grape berry moth *Lobesia botrana* Denis and Schiffermueller, and *Tephroclystia pumilata* Hübner (Silvestri 1907 and several subsequent authors), especially when other favorable host plants are near olive trees.

Zelleria oleastrella **Millière** *(Tinea oleastrella)* **(Lepidoptera, Yponomeutidae)**

Adult. The body is grey, the wings narrow, and the wing span 14-15 mm (Silvestri 1943). At rest, the adult holds its body at a narrow angle to the substrate it rests on, with the head and thorax closer to, and the abdomen and tip of the closed wings further away from, the substrate. This posture helps distinguishing this species from other microlepidoptera infesting the olive tree.

Larva. The grown larva is green, darker along the dorsum, and 8-12 mm long.

Host plants. Olive and possibly also oleaster. It is known to occur in Spain, France and Italy (Arambourg and Pralavorio 1986), but also in

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Greece (Tzanakakis and Lambrou 1972).

Life history and damage. It is multivoltine. On the basis of the time it takes for a generation to be completed during various months in southern Italy, Martelli (1915) concludes that it can complete 5 generations from April to December. The larva feeds on tender new growth externally, or bores in the tips of shoots and in buds, or mines in leaves (Silvestri 1943, Balachowsky 1966b). It overwinters in the larval stage, often inside a leaf (Balachowsky 1966b). During winter larval growth is slow. The sinuous larval mine in the leaf in winter, resembles the one made by the larva of the olive moth, *Prays oleae.* The adults appear in March-April, and lay their eggs on tender leaves, buds and shoots of the new season. The young larva enters the tip of a shoot, or connects apical young leaves with silk threads to form a nest where it settles. It comes out of the nest to feed on neighboring leaves. In other instances, especially in winter, it becomes a leaf-miner.

This moth causes no damage to grown trees, but may do so to young trees in nurseries, by destroying the apical bud, grafted buds, or the tender tips of side shoots.

Two other species of the same genus live on other Oleaceae: *Z. phillyrella* Millière on *Phillyrea* spp. in the Mediterranean region, and *Z. hepariella* Stainton on shoots of *Fraxinus* in temperate and southern Europe (Balachowsky 1966b).

***Euzophera bigella* (Zeller)** (possibly *E. egeriella* Mill.) **(Lepidoptera, Pyralidae)**

This moth has been known more as a minor pest of stone and pome fruit trees than of olive. Silvestri (1943) mentions that this moth was found in Dalmatia, Asia Minor, Syria, and from the north to the south of Italy, and that generally it occurs from western and southern Europe to western Asia. Also that it lays its eggs on the trunk and branches of olive trees with cracked bark. Recently, substantial injury to young twigs of young and mature olive trees by larvae of this moth has been reported in several localities of central Crete (Simoglou 2012a,b, and Annual Rpt. 2012 Heraklion Reg. Cntr. Plant Prot. and Quality Control). On the other hand, Arambourg (1986b) mentions that *E. pinguis* (below) is the only species of the genus *Euzophera* that is harmful to olive in the Mediterranean region. Therefore, we feel that the identity of the species of *Euzophera* infesting olive in Crete and the Greek mainland needs verification.

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Data on the moth's morphology and life history in Europe is given in the chapter on insects of stone fruit trees. Below we give only limited data concerning the olive tree.

Life history and damage. According to Silvestri (1943), the larvae enter the bark, and little by little dig a gallery mainly in the bark but also reaching the cambium and the wood. In Sicily, Tunisia and Algeria, the larvae were found only on olive trees in tubercles caused by the olive knot bacterium. According to Simoglou et al. (2012b), the larvae attack fruits during ripening but not earlier, the injury beginning in July and increasing in August and September.

Euzophera pinguis **Haworth** *(E. nelliella, E. splendidella)* **(Lepidoptera, Pyralidae)**

Adult. It is brown to brownish grey, usually with two dark grey transverse stripes on the forewings. The hindwings are greyish white, darker along the border. The wing span is 20-25 mm.

Larva. It is light green, with dark brown head and prothoracic shield. Its final length is 20 mm (Touzeau 1972).

Host plants. Olive, *Fraxinus* spp., and possibly some other Oleaceae. On olive it is generally a bark and wood borer. In Italy, larvae have been observed in the dead tumors caused to olive twigs by the olive knot bacterium *Pseudomonas syringae* pv. *savastanoi.* In other parts of Europe, including France, the larva has been reported as living mostly in the bark of *Fraxinus* (Silvestri 1951, Touzeau 1972, Arambourg 1986b). This insect is reported to occur in most Mediterranean regions.

Life history and damage. According to Touzeau (1965, 1972), who studied this insect on olive in northern Tunisia, it is bivoltine there. It overwinters as an active larva, continuing its growth during winter. It is during that season, from September to March-April, that it causes the greatest injury. Pupation occurs from the first half of March to early May. Adults of the overwintered generation emerge from caged branches from early April to early June. They deposit their eggs preferably on rough areas of the bark of the trunk and limbs. The eggs are laid singly or in groups of 5 or 6 on the bark, preferably where the bark is rough, or at the forking of branches. Touzeau (1972) states that according to Rungs (in litt.), the female lays eggs on bark injured by frost or by exposure to the sun after

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severe pruning to renew the crown of trees. Soon after hatching, the young larva enters cracks and crevices of the bark, or galleries of other insects, from where it starts its own gallery. The first young larvae of the first generation are seen in late April. They grow during the summer and pupate from the latter half of July to September. The adults occur in August and September. During these two months there is an overlap between grown larvae of the first generation and neonate ones of the second.

As reported by Touzeau (1965), in northern Tunisia this insect occurs regularly on healthy olive trees where its larvae cause serious injury by boring deep galleries in the trunk and limbs. The galleries inpede the circulation of the sap, thus causing yellowing, weakening and finally death of the part distant from the larval gallery. Because of the depth and the length of the galleries, which often reasch 10 cm, one larva in the fork of a branch is enough to cause its death. *E. pinguis* occurs on olive also in certain parts of Spain and of Morocco, where it is not considered to be an important pest of this tree. However, Arambourg (1986b) mentions that this insect is a serious economic problem in the olive-growing zone of Jaen in Spain.

Control. According to Arambourg (1986b), the relatively long period of the presence of adults in the grove, and the sites where the eggs are laid on the bark makes control difficult, and requires insecticides with long residual action to kill adults and neonate larvae as soon as they hatch from the eggs, before they penetrate the bark. The use of chlorinated insecticides being forbidden, opganophosphorous ones with the longest possible residual action should be used.

Palpita unionalis **(Hübner)** *(Margaronia unionalis, Glyphodes unionalis)* **(Lepidoptera, Pyralidae)**, comm. **olive pyralid, jasmin moth, jasmin pyralid, olive and jasmin leaf roller**

Adult. It is 11-15 mm long and has a wing span of 22-28 mm, or less so according to some authors. Wings and body are satin white, except for a fine brown line along the costa of the forewings, and sometimes a few scattered dark spots on the wings (Fig. 334). Under the white scales the body is greenish (Avidov and Harpaz 1969).

Egg. Slightly oval, flat, greenish or sometimes yellow, 1 x 0.7 mm.

Larva. The young larva is at first light brown or greenish yellow, but soon becomes greenish and subsequently shiny green to dark green,

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Figs. 334-335. *Palpita unionalis.* 334.Adult. 335. Erosion of green olives by larvae (photo B.I.K.).

with a few colorless hairs on each body segment. Along the dorsum there is a light-colored line. Fully grown it is 20-25 mm long, and its last prolegs are relatively large and exceed the end of the abdomen.

Pupa. Brown, 12-15 x 3-4 mm, in a loose, white, oblong cocoon.

Host plants. According to Martelli (1916) as cited by Silvestri (1951), *P. unionalis* lives especially on Oleaceae of the genera *Olea* and *Jasminum,* but is also observed on *Funtunia* (Apocinaceae). According to Balachowsky et al. (1972), in the Mediterranean maquis it lives on *Arbutus unedo* of the Ericaceae and on the oleaster, and passes to cultivated plants where it infests mainly olive, jasmine *(Jasminum officinale* var. *grandiflorum)* and *Ligustrum,* all Oleaceae. It seems to also infest species of other families (Antonelli and Rossi 1989). In the laboratory, the larvae developed well on *Phillyrea* and *Fraxinus* foliage (Avidov and Rosen 1961). Tremblay (1986) mentions that *P. unionalis* is rarely found on other Oleaceae, apart from olive, jasmine and *Ligustrum.*

Life history and damage. This species is widespread in tropical and mildly subtropical regions of the Old World (Avidov and Rosen 1961). According to Balachowsky et al. (1972), it originated in the Mediterranean region, where it is found from east to west, and south to the olive-growing regions of northern Africa, the Canary Islands and Madeira. Its distribution extends as far as western and southern Africa, western and southern Asia, Japan, Australia and

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tropical America (Silvestri 1951, Avidov and Harpaz 1969). It is a known pest of olive in Mediterranean countries, and a serious pest of jasmine in France and Java.

This moth is multivoltine. The number of generations, as well as the overwintering stage(s) vary with region and authors. The nutritional value of the host plant through the seasons may also affect voltinism. In Greece on olive, 4-5 generations are reported (Anagnostopoulos 1939, Zervas et al. 1989). On the basis of moth captures in black-light traps in two irrigated olive groves of east-central Greece, Zervas et al. (1989) concluded that 4 to 5 generations were completed in 1985. Moths were captured from early June to mid-November in one grove, and mostly from mid-July to mid-November in the other grove. There were 3 distinct peaks of captures in both groves, in mid-July, mid- to late August, and mid-October, and an additional low peak in June in one of the groves, suggesting 3 or possibly 4 generations. Observations by M.E. Tzanakakis in coastal Halkidiki (northern Greece) on a jasmine shrub near olive trees, lead him to conclude that in that area the generations are perhaps only two. In a low-elevation grove of irrigated young olive trees not far from the northern coast of central Crete, five-year records from a black-light trap showed great differences between years as to the times of first moth captures and population peaks. The first moths were captured from late May to mid-June, and the last few from mid-September to late October (L.G. Tzeiranakis, personal commun.). In Italy, the overlapping of generations makes difficult the determination of their number (Antonelli and Rossi 1989), while in France it has only two generations (Balachowsky et al. 1972). In Israel, Avidov and Rosen (1961) have established that in olive groves the insect overwinters at any stage of the life cycle, and that on the coastal plain and the northern Negev it completes 6 generations per year, most of which overlap one another. Avidov and Rosen determined thresholds of development and thermal constants for all preimaginal stages on various species of host plants, as well as the longevity of adults. The seasonal history of this insect in southern Europe has not been studied thoroughly. Kuchlein (1958) states that in central, northwestern and northern Europe, the moth is an immigrant, as is apparent from its distribution, the irregularity of its occurrence, the dates it is captured in traps, and its biology. The fact that in southern Europe the moth is not as common and abundant as in tropical and subtropical Africa, led him to suggest that invasions in the central and northern part of

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Europe come from Africa. In the Netherlands the moths are captured mostly in September and October, and in England fron late July to November, as has often been the case in central Greece and Crete. In southern Dalmatia a few specimens were captured in spring, but the moth was common in September.

Balachowsky et al. (1972) state that in regions with a marked winter, including the Euro-Mediterranean one, the insect seems to overwinter as larva, pupating in spring, and becoming adult from July onwards. According to Avidov and Rosen (1961), under favorable temperatures the adult females mate and start ovipositing usually during the first few days of their life. In Israel they lived on average more than a week during the hottest season, and up to 2 months in the cold season. In the laboratory they laid an average of 590 eggs per female. The eggs are deposited on leaves. Adults and larvae are nocturnal. The larvae fasten leaves together with silk threads and create a shelter where, protected, they stay during the day. During their first few days they live singly or in groups. Later, each larva lives alone. During the night they penetrate and injure apical buds, or feed on young shoots and tender leaves, first eroding the leaf epidermis, then the parenchyma, leaving the opposite epidermis intact (Balachowsky et al. 1972). As they grow they consume whole leaves, including the midvein. Under high population density they may even feed on the mesocarp of still green olives (Fig. 335,). In green olives the erosion of the mesocarp is superficial or deep (involving the whole layer of the mesocarp). Therefore, the larva lives as a leaf roller, usually in a shelter-nest of silk threads. On olive, it is a tender-foliage feeder. In Israel larvae were unable to grow on olive leaves older than a year (Avidov and Rosen 1961). According to Balachowsky and Mesnil (1935), in jasmine plantations the larva grows fast and sudden attacks are observed in May-June. The larva is very active, and when disturbed it hangs on a thread it produces and falls to the ground (Avidov and Harpaz 1969). Pupation takes place in a cocoon between leaves, in bark crevices, or in other protected sites.

Injury to leaf buds, grafts and new growth by young larvae can be serious in nurseries and newly-planted olive groves, and requires chemical control. In established groves with larger trees, effective natural enemies keep the moth population density low, and in most cases there is no economic damage. Among the exceptions is Israel, where the insect breeds the whole year round and is considered a serious pest of olive, in addition to jasmine and *Ligustrum* (Avidov

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and Rosen 1961). In established olive groves of southern Europe, population growth is favored and erosion of foliage can be extensive only under conditions of abundant and lasting new growth, as occurs after severe pruning to remove frost-damaged branches. Such dense populations and considerable injury was observed in central Italy after the frost of 1985 (Antonelli and Rossi 1989). In Greece also, dense populations of the insect and considerable injury to leaves and fruit of heavily-pruned, frost-damaged trees of the cultivars Konservolia (Amfissis) and Kalamon, was observed in certain groves of central continental Greece and of some islands (Zervas et al. 1989). Under high larval population densities, erosion of green olive fruit has been observed also in other countries and cultivars, but it is uncommon and seldom affects a considerable proportion of the crop. As a rule, the moth is considered a pest of young olive trees in nurseries and newly-planted olive groves, where it destroys grafts and by consuming a high percentage of the few leaves and apical buds, it causes the growth of many undesirable side branches.

Control. When necessary, contact or stomach insecticides against young larvae, as soon as they appear in threatening numbers, are recommended (Avidov and Rosen 1961). Organophosphorous insecticides have generally been preferred. On jasmine used in the perfume industry care is needed in the selection of the insecticide. In Egypt, the mating disruption method was tested against this moth, using the blend of two sex pheromone components (Hegazi et al. 2007). Captures of male moths in the treated plots were significantly lower than in the controls. However, the fast degradation of one of the components of the pheromone blend and the probable immigration of gravid female moths from neighbor olive groves, as pointed out by the authors, suggest further testing of the method. On ornamental ligustrum which is frequently pruned, the timely removal of new growth usually limits the development of damaging larval populations to a degree making the use of other control measures unnecessary.

Hybernia bajaria Schiffermueller, ab. *sorditaria* Hübner (Lepidoptera, Geometridae)

The identity of this species is doubtful. Isaakides (1936b) concluded that the specimens he studied from Crete belonged to an aberration of *H. leucophaearia* Schiffermuller and not *bajaria.* His conclusion agrees with the season of the year that adults of *leucophaearia* appear

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in other regions, but not with the affinity of its host plants to *Olea.* The species has already become rare in Crete and it is necessary to have specimens reidentified before it becomes extinct.

Adult. According to Isaakides (1936b), the males of the aberration he studied in Crete had a wing span of 28-35 mm and a general coloration resembling that of old olive bark. The female is apterous and 9-11 mm long. Dorsally the thorax and first abdominal segments are grey mixed with brown, and the rest of the abdomen brown.

Larva. The young larva is dark, almost black. The last-instar one is grey, greenish-grey, or brown, lighter ventrally, with two dark lateral longitudinal lines reaching the 11th abdominal segment. Anteriorly, these lines unite dorsally into a single one that extends forward to the head. When fully grown it is 32 mm long.

Pupa. It is brown and 9.5-12 x 3-4 mm. The smaller pupae give females.

Life history and damage. In the Hierapetra area of southeastern Crete, where it mostly occurred, it is univoltine (Anagnostopoulos 1931, Isaakides 1936b). It overwinters as a pupa in the soil. According to Isaakides (1936b), the adults emerge in late winter and are seen from late January to late February. The wingless female climbs the trunk up to 2 m, and after mating lays her eggs in groups of up to 60 in cracks and fissures of the rough bark. The first larvae hatch in mid-March. They first consume buds, and later, tender leaves and closed flowers before full bloom. Fully grown in late April to early May, they reach the soil, where they pupate in a cocoon at a small depth. Anagnostopoulos (1931) gives the time of occurrence of the various life stages a little later. According to Martelli (1961), probably referring to Italy, the first adults emerge from the soil from mid-March to early April.

The consumption by the larvae of buds and later of inflorescences before bloom, could annihilate the crop. However, population outbreaks were periodic, probably because of the action of effective natural enemies of the pest. Infestations have been limited to non-irrigated olive groves.

Control. Deep ploughing in summer to expose the pupae to dry heat, in conjunction with inorganic stomach insecticides against the larvae, gave satisfactory control in the first half of the 20th century. Since the advent of organic synthetic insecticides, which are used against other olive pests, this moth has become rare in Crete.

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Two more species of Geometridae have been noticed feeding on the foliage of olive in southeastern Crete: *Hemerophila japygiaria* Costa, and *Problepsis ocellata* Friv. (Isaakides 1936a). They are now rare on the island and their life history on olive is not known.

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Insects of the pistachio tree

Homoptera

- *Hysteropterum grylloides* (F.), Issidae
- *Idiocerus stali* Fieber, Jassidae

Psyllids

- *Agonoscena cisti* (Puton), Aphalaridae
- *Agonoscena pistaciae* Burckhardt and Lauterer, Aphalaridae
- *Agonoscena targionii* (Lichtenstein), Aphalaridae
- *Megagonoscena gallicolla* (Burckhardt and Lauterer), Aphalaridae

Aleyrodoidea (whiteflies)

- *Dialeurodes citri* (Ashmead), Aleyrodidae

Aphids

Brachycaudus amygdalinus Schouteden, Aphididae
Salicicola pistaciae Lind., Aphididae
Baizongia pistaciae (F.), Eriosomatidae
Forda derbasi Licht., Eriosomatidae
Forda follicularis Passerini, Eriosomatidae
Forda formicaria von Heyden, Eriosomatidae
Forda trivialis Passerini, Eriosomatidae
Geoica utricularia (Passerini), Eriosomatidae
Paracletus cimiciformis von Heyden, Eriosomatidae
Teternema lentisci Passerini, Eriosomatidae
Tetraneura cornicularia Passerini, Eriosomatidae

Coccoidea (scale insects)

- *Aspidiotus nerii* (Bouché), Diaspididae
- *Chrysomphalus dictyospecmi* Morgan, Diaspididae

Chrysomphalus inopinatus Leonardi, Diaspididae
Diaspis syriaca Lindegren, Diaspididae
Epidiaspis gennadii Leonardi, Diaspididae
Epidiaspis leperii (Signoret), Diaspididae
Leucaspis pistaciae Lind., Diaspididae

- *Lepidosaphes pistaciae* Arhangel'skaya, Diaspididae
- *Melanaspis inopinata* (Leonardi), Diaspididae
- *Parlatoria oleae* (Colvée), Diaspididae

Pistaciaspis pistaciae (Arhangel'skaya), Diaspididae
Pistaciaspis pistacicola (Bouché), Diaspididae
Salicicola davatchii Balachowsky and Kaussari, Diaspididae
Salicicola pistaciae Lindinger, Diaspididae
Suturaspis pistaciae (Lindinger), Diaspididae
Anapulvinaria pistaciae (Bodenheimer), Coccidae
Ceroplastes floridensis (Comstock), Coccidae

- *Ceroplastes rusci* L., Coccidae

Ceroplastes sinensis del Guercio, Coccidae
Pulvinaria pistaciae Gennadius, Coccidae

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Eulecanium rugulosum Ash., Coccidae
- ▪ *Saissetia oleae* (Olivier), Coccidae

Hemiptera

Acrosternum heegeri Fieb., Pentatomidae

Coleoptera

Capnodis cariosa Pallas, Buprestidae
- ▪ *Capnodis tenebrionis* (L.), Buprestidae

Scobicia chevrieri Villa, Bostrychidae
- ▪ *Sinoxylon sexdentatum* Olivier, Bostrychidae

Hesperophanes sericeus F. Cerambycidae
Clytra atraphaxidis Laicharting, Chrysomelidae
Clytra novempunctata Olivier, Chrysomelidae
Clytra vicina Lac., Chrysomelidae
Cryprocephalus fulvus Goeze Chrysomelidae
Cryptocephalus ilicis Olivier, Chrysomelidae
Cryptocephalus imperialis Laicharting, Chrysomelidae
Lachnaea orientalis Weise, Chrysomelidae
Lachnaea sexpunctata Scopoli, Chrysomelidae
Macrolenes dentipes Olivier, Chrysomelidae
Pachybrachis limbatus Menetr.,
Tituboea biguttata Olivier, Chrysomelidae
Polydrosus angustus (Lucas), Curculionidae
Polydrosus mollis Stroem, Curculionidae
Lampyris noctiluca L., Lampyridae
- ▪ *Pseudocoeliodes rubricus* (Gyllenhall), Curculionidae
- ▪ *Chaetoptelius vestitus* (Mulsant and Rey) Fuchs, Scolytidae
- ▪ *Estenoborus perrisi* Chapuis, Scolytidae

Lepidoptera

- ▪ *Thyrsostoma guerini* (Stainton), Heliodinidae
- ▪ *Archips rosanus* L., Tortricidae

Cadra cautella (Walker), Pyralidae
- ▪ *Ectomyelois ceratoniae* (Zeller), Pyralidae

Ephestia kuhniella Zeller, Pyralidae
Plodia interpunctella Hübner, Pyralidae
Recurvaria pistaciicola Danilevskii, Gelechiidae
- ▪ *Teliodes decorella* Haworth, Gelechiidae

Nepticula promissa Stgr., Nepticulidae
- ▪ *Thaumetopoea solitaria* Freyer, Thaumetopoeidae
- ▪ *Kermania pistaciella* Ams., Dinophilidae

Hymenoptera

- ▪ *Megastigmus pistaciae* Walker, Torymidae
- ▪ *Eurytoma plotnikovi* Nikol'skaya, Eurytomidae

Mart et al. (1995b) give a list of 38 species of insects injurious to the pistachio tree in Turkey. Of them they consider of economic

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importance the following eleven: *Idiocerus stali, Agonoscena pistaciae, Suturaphis pistaciae, Eulecanium rugulosum, Acrosternum heegeri, Capnodis cariosa, Chaetoptelius vestitus, Recurvaria pistaciicola, Thaumetopoea solitaria, Kermania pistaciella* and *Megastigmus pistaciae.*

Idiocerus stali Fieber (Homoptera, Jassidae)

Anagnostopoulos (1939) described a species of the same genus, which he named *Idiocerus pistaciae* Anagnos*.* However, the morphological characters he gave were not sufficient for us to decide whether the insect he described as a serious enemy of pistachio in Greece was actually *I. stali.* The latter occurs in Cyprus, and is a serious enemy of pistachio in Iran (Davatchi 1958). The seasonal development and habits of the population Anagnostopoulos (1939) described resemble so mush with those Davatchi (1958) did, that we (Tzanakakis and Katsoyannos 1995) did not exclude the possibility that they were dealing with the same species, i.e. *I. stali.* This point of view is supported also by the work of Mourikis et al. (1998).

Adult. According to Davatchi (1958), it is 3-3.25 mm long, of variable color, from greenish-yellow to brown. The head is wider than the thorax. In the female the last antennal article of the setiform antennae is long, fine and tapering, while in the male it terminates in a blackish oval palette (for details on the morphology of this species see Davatchi 1958). Mourikis (2004) gives the adult length 3.5-4.2 mm, possibly concerning individuals collected in Greece on pistachio trees of the “Aegina” cultivar.

Host plants. *Pistacia vera* (pistachio), *P. mutica,* almond, apricot (Davatchi 1958).

Life history and damage. According to Anagnostopoulos (1939), this insect completes one generation per year. It overwinters as adult. In Attica, central Greece, the adult becomes active from late April on. It pierces and sucks the sap of new growth, matures sexually and oviposits on leaf stalks, tender shoots, and axes of inflorescences. The female inserts 3 eggs in each oviposition site. Hatching of larvae is complete by early May, and their growth and development are complete by early June. They become adult approximately in mid-June. The young immature adults either remain in the pistachio orchard, or disperse to other plants until the following April. Piercing

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and sucking the sap by adults and larvae, cause the atrophy or even the death of leaves, shoots and inflorescences. Mourikis et al. (1998) are in general agreement with Anagnostopoulos (1939). They also mention the insect univoltine, infesting leaves and fruit, and causing severe injury to pistachio when its populations in spring are dense. The adults become active in April and, same as do the larvae, pierce and suck the contents of leaves, inflorescences, and later of young fruits. Rachises of panicles and young fruits become black, shrivel, and later dry out. The number of adults on pistachio trees diminishes during summer, so that only a limited number is found on the trees by leaf drop.

Davatchi (1958) found this insect in Iran also univoltine, overwintering as adult in bark fissures and under dry bark of trunks of a number of species of trees, but also in fissures of walls and telegraph poles. The eggs are inserted obliquely in incisions made by the laying female, the sides of which incisions are covered with a secretion which becomes blackish. The eggs are inserted preferably in peduncles of floral grapes, but also in leaf petioles. In each incision are 2 eggs, one near the other. A total of approximately 70 eggs per female are laid within 2 to 3 weeks, depending on temperature. In Iran, hatching of larvae coincides with the end of bloom and the appearance of the first new fruits. In addition to removing plant sap, this insect exscretes abundant honeydew which covers leaves and fruit. Fruits dry and drop. Under heavy infestation the yield is virtually annihilated. In October the adults move to their winter quarters.

Control. Anagnostopoulos (1939) recommends a spray with a summer oil at approximately the end of the hatching period (for central Greece early May), and a second one 10 days later. Various synthetic insecticides are also effective. According to Mourikis (2004), the insecticidal applications against the moth *Stathmopoda guerini* and the seed wasp *Eurytoma plotnikovi* usually suffice for the control of *I. stali.* However, if this plant hopper develops dense populations before those pests, a spray with a wide spectrum insecticide will control it.

Pistachio psyllids

In the Balkans and the Middle East, the pistachio tree, *Pistacia vera,* and wild species of the same genus, are infested by at least the three species of *Agonoscena* and one of *Megagonoscena* given on the

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above list of species infesting pistachio. The picture is unclear as to which and how many species of *Agonoscena* occur on the cultivated pistachio in each major pistachio-growing area of Greece. Based on fairly recent sources (Lauterer et al. 1998, Souliotis and Tsourgianni 2000, Zartaloudis 2003, 2010 and references therein), we could conclude that all those species of *Agonoscena* occur in Greece, and even may coexist in some orchards. Lauterer et al. (1998) give the most important morphological characters for identifying each of the three species of *Agonoscena* infesting pistachio, and distinguishing *A. pistaciae* from *A. targionii* and *A. cisti.* They further mention the similarities between the eight species of the genus *Agonoscena,* and add that *A. targionii* has frequently been mistaken for *A. pistaciae.* In a number of countries, in addition to pistachio, *A. pistaciae* has been known to live also on *P. atlantica, P. mutica, P. palaestinae* and *P. terebinthus, A. targionii* on *P. lentiscus* and *A. cisti* on *P. lentiscus* and *P. palaestinae* (Lauterer et al. 1998). *A. targionii* not long ago was reported as a serious enemy of pictachio in Halkidiki, of coastal northern Greece (Zartaloudis 2003, 2010). Samples of psyllids from pistachio also of Halkidiki, were identified by I.D. Hodkinson as belonging to the two other species, namely *A. pistaciae* and *A. cisti* (=*A. menozzii* (Laing). In the orchards where the psyllid populations were dense and the injury to the crop serious, *A. pistaciae* was the dominant species in central and southern Greece (Souliotis and Tsourgianni 2000, Mourikis 2004) and *A. targionii* in northern Greece (Zartaloudis 2003, 2010). Yet, we feel that there is need for clarifying the importance of each species of *Agonoscena* as an enemy of pistachio in various pistachio growing areas of Greece. In view of the above, we briefly give below data for both *A. pistaciae* and *A. targionii,* as given in the literature. These two species have been reported as having similar life histories.

Agonoscena pistaciae **Burckhardt and Lauterer (Homoptera, Aphalaridae)**, comm. **pistachio psyllid**

Adult. According to Davatchi (1958) it is 2-3 mm long, light yellow, with slightly darker stripes along the head and thorax. In certain individuals the intersegmental lines are darker than the rest of the abdomen. Lauterer et al. (1998) give the adult length as 1.3-1.6 mm. For details of adult characters see Burckhardt and Lauterer (1989).

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Larva. The L1 is orange and 0.2-0.37 mm long, the L4 and L5 pale yellow to greenish yellow, and the L5 1.05-1.22 mm long (Lauterer et al. 1998).

Life history and damage. According to observations in southern Iran, this psyllid overwinters as adult in fissures of the bark, under fallen dead leaves, and in other protected sites of the orchard (Davatchi 1958). The adults become active early in spring and pierce and suck the buds which burst at that time, and the young tender leaves. The eggs are laid on or near developing buds and on leaves. The larvae pierce and suck the leaves and excrete abundant honeydew which favors the development of sooty mold fungi. The adults of this first generation appear in late May to early June. Four more generations follow. The adults of the last generation go to their winter refuges in October-November.

In the Gaziantep area of southeastern Turkey, according to Celik (1981), as cited by Lauterer et al. (1998) and Zartaloudis (2003), the overwintered adults return to their host trees in late March and early April. The eggs are laid mostly on the lower leaf surface along the midrib, but also on buds. The first- and second-instar larvae go to the upper leaf surface forming small groups along the midrib. They are covered with a protective wax secretion. Older larvae disperse individually over the leaves, especially on the lower surface. Adults of the first generation appear in mid-May, and 5-6 generations may be completed in a year. In Crimea, the overwintered adults appear on the trees later, in May and until June, and 3 generations are completed per year. The adults of the first one appear in early June, of the second in mid-July, and of the third one (that overwinters) in mid-September (Loginova 1968, after Lauterer et al. 1998).

Souliotis and Tsourgianni (2000) sampled the adult and larval population in an orchard to the north, and in another to the south of Athens. According to the abstract of their paper, this psyllid is present on pistachio foliage from mid-April to leaf fall at the end of November. During the first two generations, from early April and mid or late June, the population density of the psyllid was low. From mid-August onwards the population increased rapidly, causing severe injury to the trees. The adult population density remained high until it dropped in November, when the adults at leaf fall left the trees to reach their overwintering quarters. In the south-of-Athens orchard, *A. pistaciae* completed 4 generations, as concluded from 4 peaks in adult captures shown in the respective graph, i.e. in May, June,

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August-September and September-October. In the south-of-Athens orchard, *A. cisti* also occurred from mid-April on, and remained in small to medium size populations until the end of July. A third psyllid species, *Megagonoscena gallicola* was also observed on the trees at low adult population densities from mid-July to the end of August only, this species being univoltine, and overwintering in the egg stage. In the north-of-Athens orchard the three above psyllid species were also found, and in addition *A. targionii* in one of the samples. In the August to Ocrober period, only *A. pistaciae* adults were abundant in that orchard. Yet we feel that the number of generations of *A. pistaciae* and *A. cisti* in central Greece should be clarified by further sampling of both adult and larval populations throughout the growing season, and possibly also by artificial infestations of experimental pistachio trees with single species of psyllas.

When the psyllid population is dense, the sucking of sap from leaves, shoots and buds, and the development of sooty mold may weaken the trees and affect the yield of the year, but also of the following year. Souliotis et al. (2000) also add the poor development of shoots and flower buds, premature leaf fall and fruit quality of the next year. If effective natural enemies in a pistachio orchard are lacking, dense populations of this psyllid usually develop. Souliotis and Tsourgianni (2000) and Souliotis et al. (2002) consider *A. pistaciae* as the most important psyllid pest of pistachio in Greece. Lauterer et al. (1998) consider it unlikely that this species may occur in numbers injurious to pistachio in northern and central Greece, whereas it could be a pest of that tree in southern Greece and Crete.

During the period of high psyllid population densities the activity of two predators and a parasitoid (*Phyllaephagus pistaciae* Ferrière) were noteworthy. The parasitoid reduced significantly the psyllid populations (Souliotis et al. 2002).

Control. Our first concern should be the maintenance in the orchard of effective natural enemies of the psyllid. If this is not possible, sprays will be applied with as selective insecticides as possible. Zartaloudis et al. (1996) mention that in Syria, good results have been obtained with flufenoxuron, teflubenzuron, abamectin, amitraz and methomyl. For fairly recent data from Greece, see *A. targionii* below.

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Agonoscena targionii (Lichtenstein) (Homoptera, Aphalaridae), comm. pistachio psyllid

Adult. The head and thorax are dorsally light reddish brown with yellow spots, and the legs yellow. The abdomen is dark brown. The forewings are ochreous with dark brown spots on the veins, and the hindwings whitish. The winter form is larger than the summer one and much darker, especially along the wing veins (Burckhard and Lauterer 1989, as given by Zartaloudis 2010).

Egg. It is 0.21-0.24 mm long, whitish when freshly laid, turning yellow and finally orange shortly before the larva hatches (Zartaloudis et al. 1996).

Larva. It has the typical form of psyllas of the Aphalaridae. The L1 is orange and approximately 0.2 mm long. Its antenae have 2 segments. The L2 has antennae with 3 segments, the L3 with 4 segments, the L4 with 6 segments and the L5 with 7 segments. The L5 is 0.7-0.9 mm long. For details on morphology of the adult see Davatchi 1958 and Burckhard and Lauterer (1989).

Host plants. Pistachio and certain wild *Pistacia,* considering the reservations expressed above.

Life history and damage. The data below are from Zartaloudis (2003, 2010) and concern populations of certain pistachio-growing localities of coastal northern Greece studied by him. Samples of those populations were identified by D. Hollis as belonging to *A. targionii*. The insect is multivoltine, 5-6 generations being possibly completed per year. It overwinters as adult in protected parts of the tree and under fallen leaves on the ground. The adults become active in spring, and lay their eggs singly or in groups in the developing buds or on expanding leaves on both surfaces of the leaflet lamella. Overwintered females laid eggs of the first generation mostly in May, and the larvae developed in May-June. In one locality in 1988, larvae of the following overlapping 4 generations were on the trees until late October to early November (Zartaloudis 2010). The larvae excrete honeydew, as those of other congeneric species, and when low humidity conditions prevail in the orchard as the season advances, they secrete wax filaments which cover their body and protect them from desiccation.

Injury to pistachio buds and foliage by adults and larvae causes chlorosis, slows tree development, and may affect the yield of the following year and the percentage of open nuts at harvest. In northern

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Greece, dense populations affect tree growth and the large quantities of honeydew excreted by the larvae result in the development of sooty mold fungi which, in addition to reducing photosynthesis, prevent the movement of beneficial insects on the tree. Therefore, economic loss is significant (Zartaloudis 2010).

In northern Greece, the most important natural enemies of this psylla were 3 species of predatory Anthocoridae, 2 of Chrysopidae, many species of Coccinellidae, and the parasitoid wasp *Psyllaephagus pistaciae* Ferrière (Zartaloudis et al. 2005).

Control. Z. Zartaloudis (personal communication) recommends, for coastal northern Greece, three interventions. The first to be done during the period of first infestation of female pistachio trees (May or early June). It consists of spraying a suspension of spores of the fungus *Beauveria bassiana.* This spray should be done in early morning or late afternoon, when air humidity is high and the psyllid adults less active. The diameter of the sprayer nozzles should be not less than 25 mesh, and spraying should stop before run off. The addition of a sticker to the spray liquid may increase effectiveness. Depending on prevailing temperatures and degree of infestation, a second spray may be needed in late July to early August with *B. bassiana* combined with deltamethrin, the latter having approval on pistachio by the respective state service. A third spray, with deltamethrin, is to be done after harvest, to kill the adults of the overwintering generation.

Lepidosaphes pistaciae forma *typica* Archangel'skaya (Homoptera, Diaspididae)

Adult. Davatchi (1958) gives drawings of the female body and of pygidiums of the two forms of this species.

Host plants. Pistachio, *Pistacia terebinthus,* and other Anacardiaceae (Davatchi 1958, P. Katsoyannos and Stathas 1995, and references therein). It has been known in Cyprus (Georghiou 1977), the Middle East and central Asia (P. Katsoyannos and Stathas 1995 and references therein).

Life history and damage. It was first recorded in Attica, central Greece, and its seasonal development studied for two years in the wider Athens area by P. Katsoyannos and Stathas (1995). In that area it completed 2 generations per year and overwintered as a reproductively immature adult female. Oviposition started in mid-

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March and early April in a warmer and a cooler locality respectively. In two successive years, hatching of first-generation crawlers occurred in late April and of second-generation ones in July. According to the respective graph, peaks of certain life stages in the warmer locality were approximately as follows: laying adult females early to mid-April and late June to late July, crawlers late April and mid-July for the first year, and early May and late July for the second one, L2 mid-June for the first year and late August to early September for the second one. Infestation concerned young shoots, fruit clusters, leaf blades and leaf stalks.

The other form of the same species, forma *pistacicola* Borksenius, was considered by Borkhsenius as a different species. However, Balachowsky places both forms within one species. In certain countries, both are often found on the same tree, with f. *pistacicola* found mainly on the bark of the trunk and big branches, and f. *typica* on leaves, fruits and young shoots (Davatchi 1958 and references therein).

Melanaspis inopinata **(Leonardi) (Homoptera, Diaspididae)**

Host plants. It is polyphagous. In Greece it has been recorded on pistachio, *Pistacia lentiscus,* pear, *Mespilus monogyna* Willd., *Cercis siliquastrum* L. and *Sophora japonica* L. It occurs in Italy, the Near East and the Middle East (P. Katsoyannos and Stathas 1997). In Iran it infests pistachio, *Pistacia mutica* and walnut, among other trees (Davatchi 1958).

Life history and damage. Outbreaks occurred in Attica, central Greece, where P. Katsoyannos and Stathas (1997) studied its seasonal development. It is univoltine and viviparous. It overwinters as a mated but reproductively immature adult female. Ovulation occurred in mid- to late March. Viviparity began between late April and mid-May, and ended in early to mid-June, depending on the year. L1 plus L2 covered the periods from early or mid-May to mid- or late July or even early August. Male nymphs were formed from mid June to early July. The first adult males appeared in late June or early July. Melanization of the body of the adult immature females was complete by early November. Most larvae settled on twigs more than a year old, while fewer on twigs less than a year old, on leaves or on fruits. This scale insect is a pest mostly of the woody parts of the tree.

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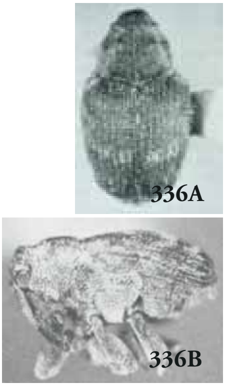
Pseudocoeliodes rubricus **Gyllenhall** (*Coeliodes rubricus*) **(Coleoptera, Curculionidae)**

This weevil has been recorded in Asia Minor, the Caucasus, the Balkans, Italy and Sicily. According to Tzanakakis (1969) who studied it in Attica (central Greece) (Fig. 336) in 1962 and 1963, this small weevil is a minor pest of male pistachio trees in central Greece. It completes one generation per year and overwinters as adult in the soil or other sheltered sites in or near the pistachio orchard. The adults come out of their overwintering quarters and fly to the trees where they are found from mid- to late March. They feed, mate,



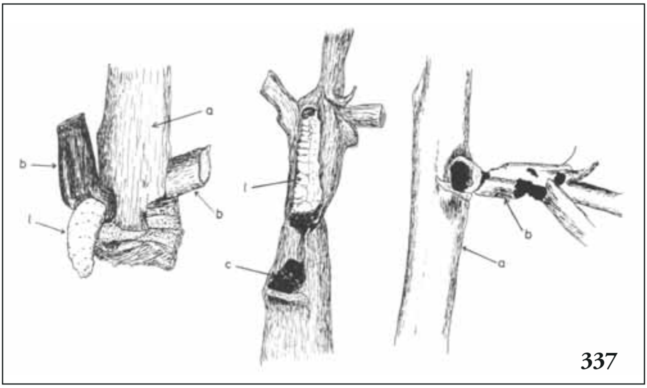


Fig. 336-337. *Pseudocoeliodes rubricus* 336.Adult in dorsal (a), and side view (b) 337.Left 3rd -instar larva (l), entering primary axis of male inflorescence (a), after having eroded the base of a secondary axis (b), which has withered. Center, rachis with parts of its wall removed, to show a 3rd instar larva (l) in it. c: entrance of larval gallery at base of a secondary axis which has fallen off. Right, injury to primary (a), and secondary (b), floral axes (Tzanakakis 1962c, 1969).

and oviposit in the inflorescences of male trees that are starting to develop at that time. The larvae bore and feed on flowers and floral axes in April (Fig. 337). When fully grown they drop to the soil and pupate in late April to early May. The adults emerge from the soil, come to the foliage and feed on the leaves for a few days in May. They cause characteristic erosions of the leaflet lamella. Subsequently they enter the soil or hide in other sheltered sites in or near the orchard and remain there in dormancy throughout the summer and winter. Further details on the life history of this weevil in Greece are given by Tzanakakis (1969). Injury to flower buds and leaves by overwintered

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Fig. 338. *Chaetoptelius vestitus.* Galleries, maternal and filial, in the outer wood of dry twigs of *Pistacia tertebinthus* (photo B.I.K.).

adults in March or by young adults in May, as well as by larvae to flowers, was never such as to reduce fruit set in adjacent female trees because of lack of sufficient pollen. Therefore, no control measures have been necessary in Greece. Limited data on this weevil's life history in Turkey (Alkan 1956, 1957, and *in litteris* 1962), are in agreement with the above.

***Chaetoptelius vestitus* (Mulsant and Rey)** *(Acrantus vestitus, Hylesinus vestitus)* **(Coleoptera, Scolytidae)**, comm. **pistachio bark beetle**

Adult. On dorsal view it is oval, almost elliptic, 2.5-3.5 mm long, and 2.5 times narrower (Russo 1926). The antennae are clubbed with distinctly voluminous the apical 3 articles. The body is generally black, or dull very dark brown, with yellow-red or red-brown antennae, legs and mouth parts. The pronotum is hairy only on the sides. The elytra have white, whitish, and brown spinelike scales between which are lines of fine hairs. The scales are white and dense at the basal part of the elytra, brown in the middle, and white and sparse in the apex. Thus, a large brown spot is formed on the elytra, which covers most of their posterior part. This large spot is angular anteriorly and has in the median line (elytral suture) a whitish or light grey line, and posteriorly two whitish kidney-shaped spots (one in each elytron). For further details in adult and larval morphology see Russo (1926).

Egg. White, ellipsoid 0.875 x 0.595 mm (Russo 1926).

Larva. It is ocher white or white yellow, apodous, and when fully grown 3.3 mm long. The head is retracted deep in the prothorax.

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The thorax is wider than the abdomen, which becomes narrower posteriorly. The body bends approximately in the 6th abdominal segment.

Host trees. Wild and cultivated *Pistacia,* such as *P. atlantica, P. lentiscus, P. mutica, P. terebinthus,* and *P. vera.* Certain earlier authors mention that this beetle may also infest olive, oleaster, *Acer campestris, Fraxinus excelsior*, *Juniperus* sp. and *Pinus* sp. (for details see Russo 1926). Anagnostopoulos (1939) reports that he found adults infesting the olive tree, boring feeding chambers like *Phloeotribus scarabaeoides. C. vestitus* is a serious enemy of the cultivated pistachio tree.

Life history and damage. According to Russo (1926) who studied this beetle in Sicily, it completes 3 generations per year. Anagnostopoulos (1939) states the same for Greece. According to Isaakides (1936a) it may complete more than one generation per year, if the adults in summer find branches suitable for oviposition. Mourikis et al. (1998) report that summer generations are completed in 30-40 days, and that the insect may thus have two and a half generations per year in Greece. These conclusions are based on the observation that reproduction galleries and oviposition occur in two or three different seasons of the year. However, this does not exclude the adults of a single generation ovipositing in three different periods. On the contrary, according to Balachowsky (1963), it seems to complete one generation per year in Italy, and the same holds for Syria and Iran. Undoubtedly, seasonal development of this bark beetle in Greece needs investigation. According to Russo (1926), in Sicily it overwinters as larva, fully grown or not, in its gallery, or as young adult in the pupation chamber at the end of the larval gallery, or as an old adult in the maternal gallery or in a feeding chamber in a twig or branch. The adults that overwintered in pupation chambers emerge in April-May and bore feeding galleries in young shoots. These galleries begin at an axillary or an apical bud, and are directed basewards of the shoot. Young shoots are often killed. Later, when the shoots harden, the feeding galleries are less deep and are always at the base of an axillary bud which is eroded and destroyed. The feeding period of adults varies and may continue until autumn or early winter when they mature sexually (Balachowsky 1963). Mature adults search weakened or half-dead twigs and branches on the trees or on the ground, to bore maternal galleries in. *C. vestitus* is monogamous. Every pair bores

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an entrance passage to the maternal gallery. The female bores and the male pushes the wood shavings out. The maternal gallery is of the "double longitudinal" type, and has a central part (prodomus), at the entrance of which mating takes place. During mating the hind part of the female body is at the entrance and the male body outside. The maternal gallery is deep in the bark, the cambium and the outer layer of the sapwood, same as in many other Scolytidae. The upper and lower branches of the gallery, i.e. the one towards the apex and the other towards the basis of the twig, have approximately the same length, 2-4 cm each, and width 1.5 mm. Along each branch of the maternal gallery the female deposits, left and right, 60-80 or more eggs. Every larva bores its own gallery, directed approximately vertically to the maternal one. As larvae grow, their galleries deviate fanwise, without one crossing another, the outer ones ultimately becoming parallel or almost so to the maternal one, while the most central ones remain vertical and the rest take intermediate directions. The larval galleries are also bored in the inner layers of the bark, in the cambium, and the outer layers of the sapwood (Fig. 338). When its growth is complete, the larva widens the end of its gallery to form a pupation chamber. Those individuals becoming adults before winter, remain in the pupation chambers and come out in April-May, after boring 1.5-mm exit holes above the pupation chambers. Those individuals that are still in the larval stage when winter comes, overwinter as such and complete the larval stage, pupate, and become adults in spring. After the completion of oviposition in the first maternal gallery, the adults may feed again for a certain period in new feeding galleries they bore, and subsequently form new maternal galleries. The adults that have overwintered in maternal galleries, abandon those shelters in spring (March) and bore other feeding galleries (Russo 1926). If the adults do not find weakened twigs or branches to oviposit in summer, they wait (usually inside feeding chambers) until autumn. Then, when the circulation of sap is low, they bore galleries in vigorous twigs. Reproduction galleries are observed also in half-dead branches or twigs that lie on the ground. Such branches of pistachio, but also of nearby wild *Pistacia terebinthus* and even *P. lentiscus,* are substrates for the developing of populations of this beetle that subsequently injure the neighboring pistachio trees.

The reproduction galleries (maternal and larval) are made mainly in weakened trees, or in trees suffering from drought. Vigorous trees, even if they have such galleries, react by producing abundant

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gum (resinous) which often causes the death of the young larvae. Consequently, even if reproduction galleries (especially larval ones) weaken and may kill branches, twigs or shoots, injury by this insect's reproduction galleries to trees that are taken care of and maintained well, is not serious as a rule. Injury by *C. vestitus* is caused mainly by the feeding galleries the adults make. When the adult beetle population is considerable, the destruction of young shoots and axillary buds affects not only tree growth of the year, but also fruit production of the following year, because of the destruction of flower buds. Mourikis (2004) considers this bark beetle as the most important wood-feeding insect pest of pistachio.

Control. Control is difficult and is based mainly on cultural measures, i.e. on the timely removal and destruction of the infested, weak, half-dead or dead branches and twigs, and on maintaining the trees vigorous with proper fertilization, irrigation and pruning. In autumn, right after leaf fall, it is recommended to cut off the weak and half-dead branches and twigs and leave them on the ground between the trees of the orchard until late February. These branches will serve as traps in which the beetles will oviposit and the adults overwinter. It is indispensable to burn these branches in late February, before the adults emerge and infest the trees. Weakened trees should also be removed from the orchard in late winter. In addition, Anagnostopoulos (1939) recommends to hang on the trees, or place near their base, half-dead twigs two-year-old or older in early December, early April and early June for adults to oviposit in and destroy those traps one to two months later. Wild species of *Pistacia* (*P. terebinthus, P. lentiscus*) that grow near pistachio orchards are sources of infestation that we should not ignore. If the above cultural measures prove insufficient, the use of insecticides will be needed at the time the adults first appear and start boring feeding galleries. To avoid insecticide toxicity to young fruits, Mourikis (2004) recommends the insecticidal sprays to be done not before the pistachios have aquired a length of 1 cm.

Another bark beetle of the same family, which infests the pistachio tree and wild species of *Pistacia* in Mediterranean countries and the Middle East, is *Estenoborus perrisi* Chapuis. The adult is brown-red and smaller than *C. vestitus.* It oviposits in branches of a medium and small diameter. Its life history in Greece is unkown. It is considered of secondary importance as an enemy of pistachio, and less harmful than *C. vestitus*, with which it often co-exists. Davatchi (1958) reports

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that it infests mostly weak trees that have already been infested by *C. vestitus* or by *Capnodis cariosa. Capnodis tenebrionis* infests non-irrigated pistachio rarely. Limited information on its life history on that tree is given in the chapter on stone fruit tree insects. Another beetle, *Sinoxylon sexdentatum,* infesting pistachio in central Greece, is treated in the chapter on insects of grapevine.

Thyrsostoma guerini **(Stainton)** *(Palumbina guerini, Stathmopoda guerini, Tinea pistaciae)* **(Lepidoptera, Heliodinidae)**

Adult. It is a small moth, 4-5 mm long, with a wing span of 12-14 mm. The general color is pale white. According to certain authors, the forewings are light grey with an oblique ocher stripe and ocher and grey spots and lines. According to other authors, the forewings are brownish, with grey or silvery spots and lines, or only with grey lines. The hindwings are grey, very narrow, and have the shape of a long and narrow trapezoid. The eyes are black, the palpi whitish, and the antennae brown (Isaakides 1936a, Anagnostopoulos 1939). At rest, the adults take a characteristic position which is typical also of other species of the same genus. Their hind (metathoracic) legs do not touch the substrate, but are directed upwards and outwards, between the prothoracic and mesothoracic legs, as is the case in certain species of mosquitoes. The adult body is at an angle of 35° to the plane of the substrate, with the head closer, and the abdomen farther from it.

Larva. It is whitish or yellow-white, with a light brown head, and a brown-black prothoracic shield separated in two parts. There are 4 small grey spots on the mesonotum, and as many on the metanotum. Fully grown it is 6 mm long.

Pupa. It is brown, and 4.5-5 mm long. It is either in the larval gallery, or in a cocoon the larva makes after cutting an oval piece of the mesocarp, 6 x 4 mm. This piece of mesocarp the larva folds longitudinally, unites its ends with silk threads, and forms a case inside which it completes its cocoon before pupating. This pupal case-cocoon is fastened at one end on the substrate (usually fruit, pedicel, or taxicarpic axis) and forms an angle of 35° with the substrate.

Host plants. *Pistacia vera, P. terebinthus, P. atlantica* and fresh galls of wild *Pistacia* caused by certain species of aphids.

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Life history and damage. According to Isaakides (1936a) it completes, in Greece, probably 4 generations per year, whereas according to Anagnostopoulos (1939) 5 generations in Attica (central Greece). On the island of Aegina, observations over six years, agree with those of Anagnostopoulos (Mourikis 2004). On wild trees of other species of the same genus it completes 2 generations, according to Real (1966). According to Anagnostopoulos (1939), who studied it in Attica, it overwinters as larva near or in buds of the apical part of shoots, and perhaps also as an egg. According to Mourikis et al. (1998), 5 generations per year are completed on the Island of Aegina, where the insect overwinters as a first-instar larva between bud scales. According to Anagnostopoulos (1939) the larvae become active at the time new vegetation of pistachio begins. They attack the apices of young shoots and the inflorescences, where they bore galleries. They become adult in mid-May to mid-June. The females oviposit on young fruits. The larvae of the first generation enter the fruits, usually at a point near their base. The larvae of following generations are also fruit borers, except those of the overwintering generation. When the endocarp is still soft, the larvae enter the inner part of the fruit and consume also the seed. Later, when the endocarp hardens, the larvae bore only in the mesocarp. The larval gallery usually has the form of a chamber. Pupation takes place in the gallery or, more often outside the fruit in a case the grown larva constructs (see above). The adults of the first generation appear in June-July, and the larvae of the 2nd generation develop at the expense of the mesocarp. Two or 3 more generations follow. The larvae of the last one overwinter. According to Mourikis (2004) the adults of the 4th generation, probably on Aegina, appear in late October and in November, and oviposit on or near buds, from which larvae of the 5th generation hatch and overwinter.

The damage caused by this insect may be serious. In spring, the erosion of tender shoots and inflorescences by larvae of the generation that overwintered is usually not serious. However, infestation of young fruits in spring by larvae of the first generation, not only destroys the fruits, but also causes fruit drop, especially in June. Later, when the endocarp has hardened, damage to the mesocarp does not appear to affect much the normal development of the fruit, but affects its appearance. In spring, but also later, the entrance hole of the larva and the destruction of much of the mesocarp and part of the epicarp, favors the entrance and spread of pathogenic fungi which cause spotting and desiccation of the fruits. That injury includes a

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change of the normal color of the endocarp, and therefore affects adversely the commercial value of the fruit. When harvest approaches and the endocarp dehisces so that part of the seed is exposed, the larva (according to Anagnostopoulos) may attack also the seed. Mourikis et al. (1998) mention that this moth is the main pest of pistachio on the island of Aegina, but is not common in other parts of Greece. On Aegina 90% of the fruit may be infested by harvest time.

On *Pistacia terebinthus* the larvae live approximately as on pistachio, but bore their galleries in the fleshy walls of galls caused to that tree by the aphids *Tetraneura cornicularia* Passerini and *Baizongia pistaciae* (L.).

Control. Among the recommended measures are the timely removal and destruction of infested fruits and shoot tips, and winter sprays in January with winter oils. In spring and summer, sprays with organic synthetic insecticides at the time of adult appearance and oviposition. But also, when the young larvae have entered the mesocarp, certain insecticides, especially organophosphorous ones, act at some depth and can kill them. The insecticides should be applied also to neighboring trees of *Pistacia terebinthus.* The insecticidal applications are usually combined with those against other insect enemies of pistachio.

Mourikis (2004), probably referring to central Greece, recommends that in late April to early May certain withered apical parts of infested shoots be caged in organdy bags, and the first insecticidal spray be applied 2 days after the first adult moth emerges in them. A second spray should follow 8-10 days later, to kill the latest-emerging moths of that generation. Three weeks later, if infested fruits are noticed, such fruits are likewise caged, and a third spray carried out 2 days after the first moth emerges in the caged fruits. If infestation in the orchard is not great, these three sprays are sufficient. Otherwise, a fourth spray is necessary 4 weeks after the third one.

Four species of moths infesting stored products have been recorded as infesting also pistachio nuts in storage in Greece. They are *Cadra cautella, Ephestia kuehniella, Plodia interpunctella* and *Ectomyelois ceratoniae* (Mourikis 2004 and references therein). For the last one see also insects of walnut and carob in this book.

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Thaumetopoea solitaria Freyer (Lepidoptera, Thaumetopoeidae)

A pistachio twig with a group of approximately 50 larvae of this insect was brought to the Benaki Phytopathological Institute Kifissia, Greece, in mid-July 1946. The infested twig was from a pistachio orchard in a northern suburb of Athens. A few trees of *Pistacia terebinthus* were also in that orchard. Isaakides (1947) reared those caterpillars in the laboratory to full growth, and obtained most adults in the first half of September. Scientists of the British Museum and of the Imperial Institute of Entomology identified the species.

Adult. Isaakides (1947) gives details of the morphology of the adults he obtained in 1946. The wing span of his male specimens was 28 and of female 33 mm. The body was grey, the abdomen covered with orange short hairs and the antennae of both sexes and the legs orange. The forewings were grey with black markings and a black costa. In the male the forewings were lighter and with more distinct markings than in the female. The hindwings were white with white fringes. Similar are the color and body dimensions of adults given by Halperin (1983) for Israel, i.e. grey forewings, white hindwings, male wingspan 20-28 and female 25-35 mm.

Egg. The eggs are in flat hexagonal clusters attached to the bark and covered with dark grey scales.

Larva. According to Halperin (1983), the neonate larva is 1.6-2.0 mm long, with an inverted Y on the back of its head. The L3, at the end of the third stadium, is approximately 6-7 mm long. On the back of its 8th abdominal segment there is a dark tuft of urticating hairs. The L4 is approximately 12-16 mm long and has tufts of urticating hairs on abdominal segments 1-8, but only on the 8th they are numerous. The L5 (last instar) is 24-30 mm long, with a head 2.4-2.6 mm wide in the male and 2.7-2.9 in the female. Its body is black dorsally, greenish ventrally and grey pleurally, with long bright hairs, and with numerous urticating hairs on all tufts of segments 1-8.

Host plants. Zeitz (1913) (from Isaakides 1947) reported it on *Pistacia terebinthus* from European Turkey and Asia Minor to Syria. In Thessaly (eastern central Greece) A.G. Koutroumpas (personal communication to P.A. Mourikis) observed it on *P. terebinthus* and *P. lentiscus,* and less often on pistachio adjoining wild *P. terebinthus* (Mourikis 2010). In Iran it was recorded on *Pistacia vera, P. mutica and P. terebinthus* (Davatchi 1958). In Israel it occurred mostly on *P.*

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palaestina and *P. atlantica,* and occasionally on *P. lentiscus, P. vera* and *Schinus terebinthifolius* (Halperin 1983).

Life history and damage. The moth is univoltine. According to Halperin (1983) oviposition in Israel occurs mostly in October on thin twigs, 3-12 mm in diameter. There is an embryonic diapause that lasts several months. Larvae hatch at the time of leaf flush of *Pistacia.* They are leaf-eaters, and under high population density may cause serious defoliation of the tree. They are gregarious, contrary to what one might expect from the species' name. Pupation occurs in the soil. There is a prolonged pupal diapause lasting one or two years.

According to a personnal communication by A.G. Koutroumpas to the senior author, the larvae in Thessaly hatched in spring of a given year, when the leaf buds of pistachio started to swell. In that year, the neonate larvae from a given egg mass remained for a number of days together, until the pistachio buds started to develop and young leaves were available for the larvae to feed on. The larvae completed growth between the 10th and 30th May, and pupated on the soil surface singly, under fallen leaves. From pupae maintained in Koutroumpas' laboratory in a suburb of the city of Volos, adults emerged between the 3rd and 11th September. They mated and laid the evening of the day they emerged. North of Greece in the Northeren Republic of Macedonia, the hatching of larvae from the overwintered eggs occurred at the end of April. Larval development lasted 73-77 days plus approximately a week in the soil before the spinning of cocoon and pupation. Adults were seen from mid-August to mid-September (Serafimovski 1975, from Halperin 1983).

In Israel, Halperin (1983) reported it as the most important pest of the genus *Pistacia.* The urticating hairs of the larvae also make it a health hazard, causing dermatitis and less often conjunctivitis, especially to schoolchildren near infested trees. This injury to humans occurs not only in April when the larvae are in their last two instars, but also through summer, because the urticating hairs remain attached to the shed larval exuvia and their toxicity persists for several years (Halperin 1983).

Control. In Greece, serious damage of pistachio has thus far occurred only in proximity to wild *P. terebinthus* and only in years when a substantial percentage of the trees had egg masses the previous winter. In such a case, an insecticidal spray soon after larval hatching will suffice. The spray program applied to pistachio orchards of Greece against other insect pests usually suffices to keep *T. solitaria* under control.

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Teliodes decorella (Haworth) (Lepidoptera, Gelechiidae)

It has been reported under several synonyms. Silvestri (1943), under the name *Andrasteia humeralis* Zeller and commonly tignola del pistachio, gives the morphological characters of adults, larvae and pupae. According to him, this moth is found from England and central Europe to all regions of the Mediterranean. It is a polyphagous leaf-feeder. In Sicily the adults appear in June. The larvae feed on the leaves of various species of *Pistacia* and species of various other plant families. Tsourgianni et al. (1994), reported that, in addition to pistachio, the species on the island of Euboea was collected on *Quercus* spp., *Abies* sp. *Cotinus coggygria, Cornus mas, Swida sanguinea* and *Phillyrea* sp. In Cyprus Georghiou (1977) reared it from *Pistacia terebinthus.* Tsourgianni et al. (1994), found the larvae causing severe injury to tender pistachio foliage on the island of Aegina. On that island, it was recorded in a number of consecutive years on pistachio, especially in early May, on tender leaves of shoot apices. The larva bands leaves together, or later folds them to form a tunnel inside which it lives and develops. The adults on Aegina had black forewings, grey hindwings, and a wing span of 12-12.5 mm. The larvae were light green and 6.5 mm long when fully grown. One generation was completed per year on pistachio.

Kermania pistaciella Ams. (Lepidoptera, Dinophilidae), comm. **pistachio twig borer**

This moth is one of the main pests of pistachio orchards of Turkey. It is univoltine. According to Mart et al. (1995a), it overwinters as larva in pistachio twigs. Pupae are formed in the twigs in spring. The adults emerge from late April, and are seen through May. The larvae feed on terminal buds injuring the growing point, and also inside shoots and twigs, causing fruit bud drop and twig death. They also injure fruit clusters. Chemical control is directed against the adults. An application is recommended one week after the first adults appear in the orchard, and repeated 10-15 days later.

Megastigmus pistaciae Walker (*Trogocarpus ballesterii*) (Hymenoptera, Torymidae)

Adult. The female is 4-6 mm long. It has a golden yellow general

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color, with grey-yellow head, red eyes, and reddish reflections on the abdomen. The forewings have a dark oval spot near their front side. The male is yellow-red. Davatchi (1956) obtained only female adults from his repeated rearings in Iran. He gives details on female morphology, and mentions that males are rare in almost all species of the genus *Megastigmus.*

Egg. Oblong, stalked, whitish.

Larva. White-grey, apodous, with a curved body, tapering at the two ends, and final length 6 mm.

Pupa. Of the free type, inside the infested fruit.

Host trees. *Pistacia vera, P. terebinthus, P. lentiscus* and other species of *Pistacia* (Rice and Michailides 1988 and references therein).

Life history and damage. It completes one generation per year. According to Anagnostopoulos (1939), who studied this insect in Greece, it overwinters as larva, not fully grown, inside the seed (endosperm) of fruits that remain on the host tree, or of fruits that have fallen to the ground, or even taken to the warehouse. The larva continues its growth and erosion of the seed in spring, and pupates in the seed in late May to early July. The adults are formed from early June to mid-July. To come out of the fruit, the young adult opens with its mandibles a hole in the hard endocarp and the mesocarp. After mating, the female inserts an egg in the endosperm of a fruit, after piercing the pericarp with its ovipositor. The larva feeds on the seed without cosuming all of it, and completes its growth the following spring. According to Anagnostopoulos (1939), a certain percentage of the larvae completes growth, becomes adult and emerges from the fruits in August-September in Attica. Those early adults do not produce progeny, because at that season there are no fruits at a stage suitable for oviposition. In California, according to Rice and Michailides (1988), the adults emerge from infested pistachios in June. In that state too, a second period of adult flights is observed in August and September. Whether the adults of this period oviposit or not, and in fruits of what species of plant, is a question to be answered. According to Mourikis (2004), on the island of Aegina, the adults begin to emerge in mid to late June.

Davatchi (1956) reports 2 generations per year in Iran, overwintering as last-instar larva, and pupation in spring when the pistachio trees are in bloom.

M. pistaciae may co-exist in the same orchard with *Eurytoma*

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plotnikovi. According to Anagnostopoulos (1939) *M. pistaciae* causes little damage to pistachio in Greece, destroying only up to 5% of the fruits. On the contrary, it destroys a considerable percentage of the fruits of *P. terebinthus.* According to the same author, the low percentage of infestation of pistachios may be due to the time of appearance of the adults of this seed wasp. At that time the endocarp of most pistachios has become too hard for the female's ovipositor to pierce. On the contrary, the fruits of *P. terebinthus* are then quite suitable for oviposition.

Control. Collection and destruction of infested fruits of pistachio and of nearby *P. terebinthus* is recommended during the period August-April. This measure also reduces the populations of *Eurytoma plotnikovi* and *Thyrsostoma guerini.* Also, sprays are recommended with a synthetic organic insecticide, usually in June-July, to kill the adults and the young larvae. Such a spray will probably be directed also against other, more important pests of pistachio (see also *E. plotnikovi).*

Eurytoma plotnikovi **Nikol'skaya** *(E. pistaciae)* **(Hymenoptera, Eurytomidae)**, comm. **pistachio seed wasp, pistachio eurytoma**

Davatchi (1956) states that, according to information communicated to him by M.Ch. Ferrière, there are two species of *Eurytoma* infesting plants of the genus *Pistacia* in Europe: *E. terebinthi* Rondani infesting *P. terebinthus,* and the other infesting *P. vera.* The species Davatchi studied on pistachio in Iran and described its morphology and life history, agrees morphologically with *E. plotnikovi* Nikol'skaya. Subsequent publications also consider *E. plotnikovi* as the pest of pistachio in Europe. Unless there is convincing systematic work to the contrary, we also consider that the species of seed wasp infesting pistachio in Greece is *E. plotnikovi,* and that Anagnostopoulos who studied its life history in Greece misnamed it *E. pistaciae* Anagnos.

Adult. According to Anagnostopoulos (1935, 1939), the female is 5 mm long, with brown-red head and thorax, yellow-red abdomen and red eyes (Fig. 339). The antennae have 11 segments, and their basal segment is three times as long as each of the next ones. The male is approximately 4 mm long, black, with yellow-red legs. Davatchi (1956) gives for the individuals he studied the female's length at 4-4.5 mm.

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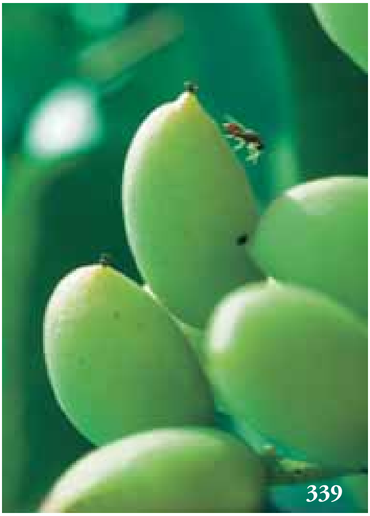
Egg. White, stalked, approximately 1 mm long.

Larva. Whitish, narrower at the two ends, apodous, curved, and 6 mm long when fully grown (Fig. 315).

Pupa. Of the free type, 5 mm long.

Host trees. *Pistacia vera, P. terebinthus.*

Life history and damage. It completes one generation per year. Perhaps some individuals complete their life cycle in 2 years. It overwinters as a fully grown larva in the infested fruits that usually remain on the tree or fall to the ground (Fig. 340). According to



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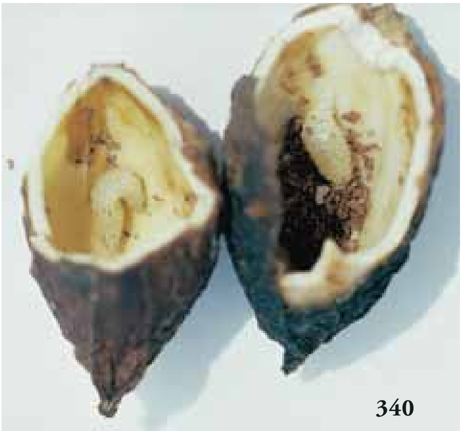

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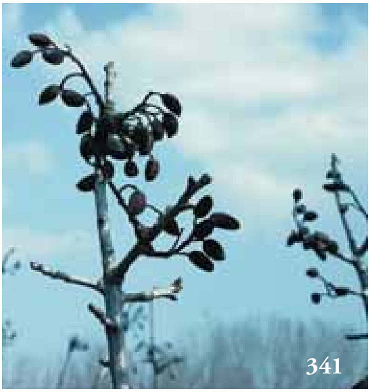

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Figs. 339-341. *Eurytoma plotnikovi.* 339.Adult female before it oviposits. 340.Fully grown whitish larvae inside infested and mummified fruits. 341. Mummified pistachios containing larvae on the trees in winter (photo B.I.K.).

Anagnostopoulos (1935, 1939) who studied this insect in central Greece, pupation takes place inside the fruits in mid-May, and adults emerge from late May to late June. In the Thessaloniki area of coastal northern Greece pupation takes place also in May (Haralambidis and Tzanakakis 2000). A mass emergence of adults was observed in that area in the

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last 10 days of May, and adult activity up to the first 10 days of June (B.I. Katsoyannos, unpublished data). In the Nicosia area of Cyprus the adults emerge also in May (Melifronides and Zyngas 1982). In an orchard within the wider Athens city area, Lykouressis et al. (2008) caged infested fruits in plastic mesh bags on the trees in October. The adults emerged from mid- to late May. To come out of the fruit, the adult opens with its mandibles a hole near the base of the fruit. The percentage of males is very low, approximately 2-3%. Oviposition takes place in June. The female inserts an egg near the apical part of a young fruit. The oviposition hole takes a dark color and is easily detected. From this hole pathogenic fungi often enter and spread to the mesocarp, causing additional injury to the fruit. The stalked egg usually lies on the inner wall of the endocarp. According to Anagnostopoulos, the young larva, in June-July, eats the inner layers of the still tender endocarp and later, in July-August, the seed. It completes its growth in August-September and remains in the fruit, in dormancy, until the following spring. Its dormancy includes a period of diapause that is terminated in mid-spring and its completion is affected by temperature and photoperiod (Tzanakakis et al. 1992). Infested fruits become mummified and as a rule remain on the tree after leaf fall in autumn (Fig. 341), in contrast to uninfested fruits. If certain fruits drop to the ground early (June), before the seed has developed sufficiently, the larva has not enough food, and ultimately dies. If fruits fall off the tree later, the larva continues its growth and development, and emerges as adult in the following May-June. Davatchi (1956) mentions that before ovipositing, the female pierces with its ovipositor the pedicel of the fruit, probably to retard its development, and subsequently introduces its egg in it.

This seed wasp is one of the most serious enemies of pistachio in Greece. Anagnostopoulos (1939) reports damage between 10 and 95% of the crop.

Control. Collection and destruction of all infested fruits after harvest, whether they remain on the tree or have fallen to the ground. This collection should be done before May. If this measure is not taken carefully in a whole area, so as to minimize the danger, a spray of the trees should be done with an organic synthetic insecticide, preferably systemic. The time to spray is determined by following the emergence of adults from infested fruits that are maintained in cages in the open. In Cyprus, a spray 3 days after the emergence of the first adults from caged fruits protected the fruits satisfactorily.

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The systemic insecticides were methomyl, oxydemeton methyl, and phosphamidon, and the contact one was cypermethrin (Melifronides and Zyngas 1982). Lykouressis et al. (2008) had no adults emerging from infested fruits maintained on the soil surface or buried in the soil from autumn to early spring. They conclude that there is no need to burry infested fruits by tillage, but just to remove them from the trees and leave them on the ground. However, the value of such a procedure should be verified for a number of years, in various areas, with different types of soils and orchard conditions, before it is recommended as a standard practice to control this wasp.

Data on some more minor pests of pistachio in Greece are given by Tzanakakis (1962a, 1962b), Tzanakakis et al. (1963), Santas (1985), Mourikis et al. (1998) and Mourikis (2004). Davatchi (1958) gives details on the life history and polymorphism of the gallicolous aphids of plants of the genus *Pistacia.*

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Insects of the fig tree

Isoptera (termites)
- *Kalotermes flavicollis* F., Kalotermitidae

Homoptera
- *Homotoma ficus* (L.), Psyllidae
  Trioza buxtoni Laing, Psyllidae
- *Metcalfa pruinosa* (Say), Flatidae
- *Dialeurodes citri* (Ashmead), Aleyrodidae
- *Parabemisia myricae* (Kuwana), Aleyrodidae

Coccoidea (scale insects)
  Lepidosaphes conchyformis (Gmelin), Diaspididae
  Lepidosaphes minima (Newstead), Diaspididae
  Quadraspidiotus ostreaeformis (Curtis), Diaspididae
- *Ceroplastes rusci* L., Coccidae
- *Coccus hesperidum* L., Coccidae
- *Planococcus citri* (Risso), Pseudococcidae
- *Planococcus ficus* (Signoret), Pseudococcidae

Coleoptera (beetles)
  Hypothenemus aspericollis Wollaston, Bostrychidae
  Scobicia chevrieri Villa, Bostrychidae
- *Sinoxylon sexdentatum* Olivier, Bostrychidae
  Carpophilus hemipterus (L.), Nitidulidae
  Hesperophanes sericeus F., Cerambycidae
  Mesosa curculionoides L., Cerambycidae
  Morimus lugubris F., Cerambycidae
  Niphona picticornis Mulsant, Cerambycidae
  Trichoferus cinereus de Villers, Cerambycidae
  Trichoferus griseus F., Cerambycidae
  Hypoborus ficus Erichson, Scolytidae

Diptera (flies)
- *Silba adipata* McAlpine, Lonchaeidae
  Drosophila melanogaster Meigen, Drosophilidae
- *Ceratitis capitata* (Wiedemann), Tephritidae

Lepidoptera
- *Anthophila nemorana* Hübner, Glyphipterygidae
  Cadra cautella (Walker), Pyralidae
- *Ectomyelois ceratoniae* (Zeller), Pyralidae

Hymenoptera
- *Blastophaga psenes* (L.), Agaonidae

This chapter concerns the insects of the common fig tree, *Ficus carica* L. The fruits of the edible fig tree, i.e. the figs we eat, are

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called syconiums. As Galil (1977) gives it, “the fig syconium is an urn-shaped receptacle whose inner surface bears the flowers and whose top is closed by a series of imbricated (overlapping) scales, the ostiole.” The common fig tree has two forms or subspecies: the edible or cultivated tree, with its various cultivars and edible fruits on one hand, and the wild or male tree or caprifig on the other. The wild fig tree produces three crops of caprifigs (for details see Grandi 1920, 1962). The pollination of figs involves a relationship with the “fig wasp” which is given at the end of this chapter (see *Blastophaga psenes*).

***Homotoma ficus* (L.) (Homoptera, Psyllidae)**, comm. **fig psylla**

Adult. It is yellow-green or green, with a light brown mesonotum, and 3-5 x 1.3 mm (Fig. 342).

Larva. The young larva is yellow-green, elliptic, with antennae of 2 segments, and approximately 0.4 mm long (Fig. 343). The grown (last instar) larva is of lighter color, pear-shaped, and 2.5 x 2.6 mm. It has many short hairs and antennae of 3 segments, the first two of which are very short and the third one long and conical apically (Figs. 344, 345).

Host trees. The common fig, *Ficus carica,* edible and wild.

Life history and damage. It has one generation per year. It overwinters in the egg stage on the tree, on or in the buds (between bud scales). In southern Italy, when the growth of the fig tree starts in early March, the eggs turn orange, and in mid- to late March the larvae hatch (Boselli 1928). The young larvae remain protected in the opening buds. During the third stadium and later they are found on the underside of leaves. They complete growth approximately in mid-May, and become adult in late May to mid-June. The adults remain reproductively immature on the underside of leaves the whole summer, and mature in early autumn. They oviposit in September and October, then die. Anagnostopoulos (1939) considers this psylla harmful to leaves and fruit, while other authors do not consider it harmful to the fig tree.

Control. If the population is dense, a spray is recommended against the young larvae in spring, with a summer oil emulsion, or a synthetic organic insecticide.

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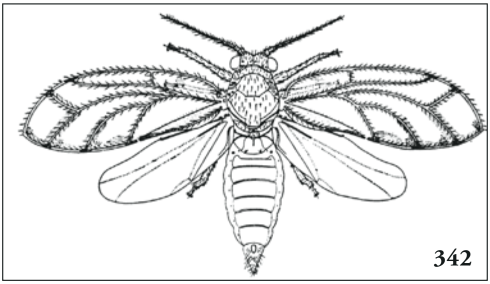

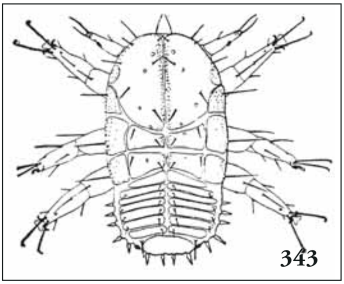

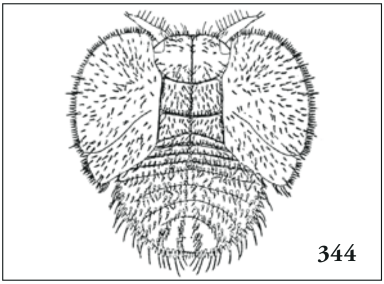

Figs. 342-345. *Homotoma ficus.* 342. Adult female. 343.First-instar larva. 344.Last-instar larva (Boselli 1928). 345.Last-instar larva (photo N.T. Papadopoulos).

Ceroplastes rusci **(L.) (Homoptera, Coccidae)**, comm. **fig scale, ceroplastes**

Adult. The female is approximately oval, 3-5 mm long, 2-3 mm wide, and 2-3 mm high. The back of the body is covered by 9 wax plates. Of them the central one is large and octagonal, and is surrounded by 8 smaller, almost tetrapleural, plates (one anterior, one posterior, and six pleural). Every one of the 8 perimetral plates has white wax filaments at its center. The general color of the plates, therefore of the insect as we see it on the trees, is almost white or white-grey, approaching pink. The shape of the back of the body reminds one of the carapace of a turtle (Fig. 346). Under the wax plates the body is red-purple. Shortly before oviposition starts, the body becomes hemispherical (Isaakides 1936a). The eggs are laid under the female's body. The male has the color of rust, is winged, and 1-1.2 mm long. In certain countries no males have been observed.

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Larva. The young larva is at first star-shaped and red. Later it looks whitish, because of the wax filaments that cover it (Fig. 347). Except during oviposition, the adult female can walk and move, as also can the larvae.

Host trees. Primarily the fig tree, and secondarily other trees and shrubs such as mulberry, citrus, apple, pear, quince, persimmon, grapevine, *Pistacia terebinthus, Nerium oleander,* and myrtle.

Life history and damage. According to Anagnostopoulos (1939), it completes 2 generations per year in central and southern Greece. It overwinters as a reproductively immature adult female on twigs of the tree. The females mature reproductively and lay in May 1000-1500 or more reddish eggs, under the maternal body. The larvae of the first generation hatch in June, disperse, and settle mainly on the leaves (Fig. 348). Later, when they are more developed, they move to leafstalks, shoots of the season and fruits, where they remain also as adults (Figs. 349, 350). They become adult in July. The larvae of the

Figs. 346-350. *Ceroplastes rusci.* 346. Adults on fig shoot. 347.Larvae on a leaf. 348.Larvae and adults on a leaf. 349.Adults on leaf stalks, shoot and fruits. 350.Adults parasitized to a high percentage. In some of them the exit holes of their parasitoids are seen (photo B.I.K.).

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2nd generation hatch from the third decade of August to the first decade of September. In autumn, before the leaves fall, the larvae abandon them, and migrate to the shoots, where they become adult in late autumn, and overwinter.

Argyriou and Santorini (1980), studied the scale insect's life history for 2 years in the same two areas of Greece. They observed approximately the same seasonal development as Anagnostopoulos (1939), and gave more details. The crawlers of the first generation settled mostly on the upper leaf surface, whereas a small percentage of them on the underside along the veins. According to their graph concerning Attica, central Greece, ovipositing females were recorded from mid-April to late June, and from early August to mid- or late September for the first and the second generation respectively. Crawlers were recorded from early May to early July, and from mid-August to late September, L1 to L3 from mid-May to mid-August and from late August to late December, whereas preoviposion adult females from mid-July to mid-September and mid-November to mid-June of the next year. Mating in the second generation was observed in the first decade of August. In the warmer Messinia area of southern Greece, the preimaginal stages of both generations developed approximately 2 weeks earlier than in Attica.

The sucking of sap by this insect delays the development of shoots and fruits. In addition, the excretion of abundant honeydew favors sooty mold fungi. This scale insect's populations fluctuate widely from year to year. This is attributed to its effective natural enemies, as are the lepidopteran *Eublemma (Ciccidiphaga) scitula* Ramb., the hymenopteran *Scutellista cyanea* Motsch., other parasitoid hymenopterans (Fig. 350), and ladybird beetles of the genera C*hilocorus* and *Exochomus* (Figs. 234, 236).

Control. When needed, sprays with a summer oil emulsion, an organophosphorous, or a carbamic insecticide have been carried out in summer, when larval hatching was complete, most larvae being in the crawler stage and some in the settled first instar. Anagnostopoulos (1939) considers one spray during the third decade of June sufficient. On cultivars needing caprification to set fruit, he suggests the spray to be done in afternoon hours, when the fig wasps do not fly. Against the overwintering adults of the second generation, a winter spray may also be applied, with a winter oil emulsion. Certain authors recommend the removal and

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destruction of the leaves in autumn, before the young larvae of the 2nd generation migrate from the leaves to the shoots and twigs.

Silba adipata **McAlpine (Diptera, Lonchaeidae)**, comm. **black fig fly, fig lonchaea**

This insect was studied extensively in Italy by Silvestri at the beginning of the 20th century, but he misidentified it as *Lonchaea aristella* Becker. Under this name, and also as *Carpolonchaea aristella* it has been mentioned by subsequent authors until 1983, when the matter was clarified by B. Katsoyannos (1983a). *Lonchaea aristella* is a different species, which does not infest figs.

Adult. The body is glossy metallic black, with slightly greenish or purplish reflections, 3.5-4.5 mm long, and with a wing span of 8 mm (Fig. 351). The compound eyes are brown or brown-red, the venter of the abdomen brown, and the legs dark brown. The female has a pointed retractible ovipositor.

Egg. White, oblong, 0.9 x 0.22 mm, narrower in the two ends, almost spindle-shaped (Fig. 353).

Larva. White, long and narrow, narrower anteriorly, of a general shape resembling that of larvae of tephritid fruit flies, and with a final length of 6-8 mm.

Pupa. Its integument is dark brown and it is 3,5-4 mm long.

Host plants. Edible figs and wild figs (caprifigs), that is the syconiums of the common fig, *Ficus carica,* as well as those of *F. pseudocarica* in Mediterranean countries and Iraq. In Algeria it develops also on *F. pseudocoriaria.* It seems to prefer the caprifigs.

Life history and damage. It completes 4-6 generations per year. According to Silvestri (1917) it overwinters possibly as adult. However, inside wild figs larvae are observed even in December, which develop to pupae and adults that will emerge in spring. In Lebanon it is reported to overwinter as pupa in the soil (Talhouk 1969). The adults suck excrement of scale insects, sweet exudates of ripe figs, and fresh or dry milky sap of fig trees exuded from injured leaves or other tree parts (B. Katsoyannos 1983a and others). In spring, after they feed, mature sexually and mate, the females begin to oviposit, usually in April and exceptionally in March. The female inserts its ovipositor between and beneath the scales protecting the ostiole (eye) of the syconium (fig "fruit") and deposits its eggs in small groups (B.

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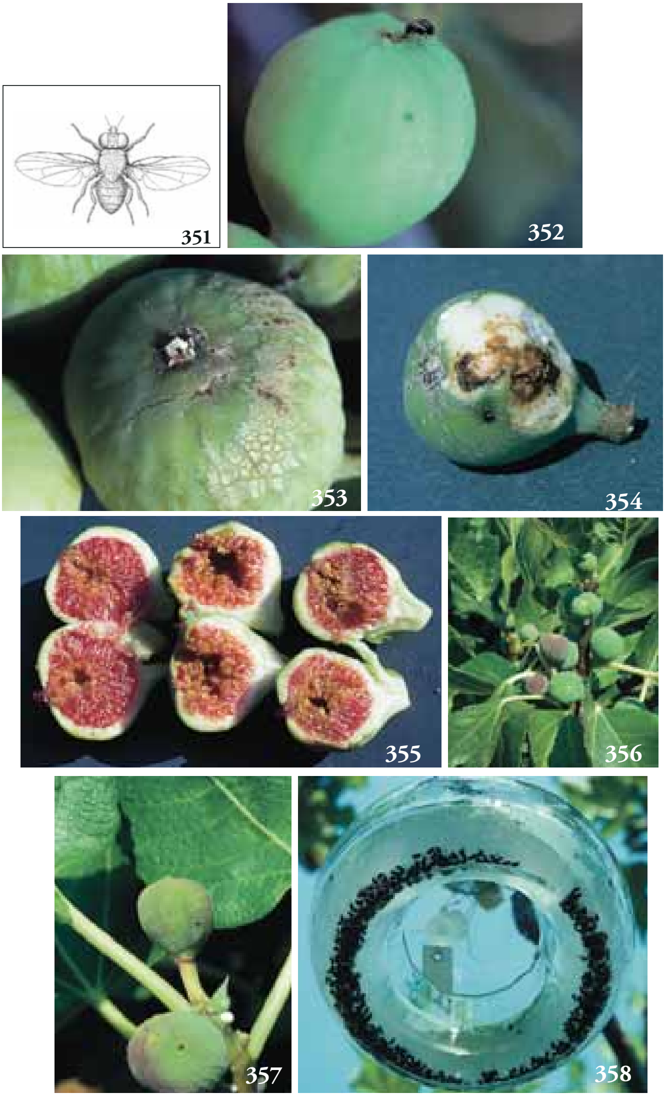

Figs. 351-358. *Silba adipata.* 351.Female adult (Silvestri 1917). 352.A female ovipositing on the fig ostiole (eye). 353.Group of eggs (white) at the eye of an almost ripe fig. 354.Injury by larvae to an unripe fig. 355.Development of infestation in ripe figs. 356.Infested (purple) and uninfested (green) figs. 357.Figs with holes of exit of fully grown larvae. 358. Adults caught in a McPhail trap with hexanol, as seen from below. On the inside of the trap the plastic vial containing the hexanol can be seen (photo B.I.K.)

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Katsoyannos 1983a). Oviposition occurs preferably in unripe figs, but ripening ones are also infested (Fig. 353). Talhouk (1969) reports that the female lays only 2-4 eggs every time. This he concludes from the fact that when there are more than 4 larvae per fig, they are almost always of two different sizes, therefore of different age. In Turkey as many as 35 larvae have been observed per fig, and in Israel as many as 30. On Chios island, B. Katsoyannos (2004) obtained 63 pupae from a single infested unripe fig, this indicating multiple oviposition. The larva enters the inner part of the syconium where it ultimately bores a gallery. Feeding on the tissues of the syconium, the larva destroys the fruit. As a rule, the larvae bore in the flesh near the surface of unripe figs (Fig. 354). In ripe figs, which they also infest, the larvae are found usually towards the center (Fig. 355). Infestation of the fig by *S. adipata* causes also rotting. Exteriorly the fig changes color. It becomes yellowish, brown, or purple (Fig. 356), and usually drops early. This premature fruit drop is frequently mistaken by growers as due to physiological problems of the trees. The fruit's infested side is soft. The grown larva opens a hole in the skin (Fig. 357), abandons the fig and drops to the soil where it pupates at a small depth, up to 10 cm. The adult emerges after a few days and oviposits in edible figs as well as in caprifigs. *S. adipata* oviposits and its larvae can grow and develop in both unripe, ripening, and even ripe figs, in contrast to the Mediterranean fruit fly which oviposits only in figs approaching ripeness. From April to November one generation follows another, faster in summer and slower in spring and autumn. *S. adipata* is a serious enemy of fig production. By destroying the caprifigs in autumn it reduces substantially the population of the fig wasp *Blastophaga psenes* which overwinters in them, therefore it reduces the degree of pollination of the first crop (brebas) of edible figs in spring. Furthermore, it destroys a portion of the spring crop of caprifigs which are needed to pollinate the second (main) crop of edible figs. Finally, it also destroys a condiderable percentage of edible figs. In ripe or almost ripe edible figs, there may coexist eggs and larvae of the black fig fly and the Mediterranean fruit fly (B. Katsoyannos 1983a, and unpublished data).

Control. Hexanol, a generally-occurring plant volatile chemical, was found to be strongly attractive to adult black fig flies, and selective, especially for females. This alcohol, in combination with a solution of 2% ammonium sulfate in transparent McPhail fly traps (B. Katsoyannos and Guerin 1984) may help substantially in monitoring

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adult fly populations, to determine the proper time for insecticide sprays (Fig. 358). This alcohol may possibly also help in controlling this insect by mass trapping. Among the various insecticides that have been used against this fly are the organophosphorous dimethoate and thrichlorfon, usually in bait sprays. The spray liquid contains the insecticide and a protein hydrolyzate, and is sprayed on part of the foliage of every 2nd or 3rd tree. Other measures recommended in older days were the use of resistant cultivars, having a small and concave "eye", the removal from the orchard of wild figs after the period of pollination of edible figs, and the timely collection and burrowing to a considerable depth (80 cm) of infested edible figs and caprifigs.

On Chios island, the parasitoid *Pachycrepoideus vindemmiae* Rondani (Hymenoptera, Pteromalidae) emerged from *S. adipata* pupae. Near fig and mulberry trees, swarms of adults of another species of the same family (Lonchaeidae) *Lamprolonchaea smaragdi* (Walker) were observed (B. Katsoyannos 1983b). The larvae of this species develop in various overripe fallen fruits that have already been infested by other insects, as for example figs or sour oranges infested by the Mediterranean fruit fly.

Anthophila nemorana **Hübner** *(Simaethis nemorana, Hemerophila nemorana)* **(Lepidoptera, Glyphipterygidae)**, comm. **tignola del fico**

Adult. It has a wing span of 14-20 mm and a shape that reminds moths of Tortricidae. The forewings have their anterior margin arched and their exterior one slightly wavy (Fig. 359). Their basic color is light brown-red, with two cross whitish zones. The hindwings are darker, with a light longitudinal median zone and two yellowish spots in the middle of their outer margin. When at rest, the adults keep their forewings approximately parallel to the substrate and half closed, so that on dorsal view they take the form of an equilateral triangle.

Larva. According to Silvestri (1943), the grown larva is 12 mm long, generally green-yellow, with three lighter longitudinal lines, one median dorsal, and two pleural ones, with black setiferous tubercles. According to Picard (1919) the grown larva is as long as 20 mm, light green, and the longitudinal dorsal and pleural lines are darker than the base body color. The head is light-colored, usually light brown,

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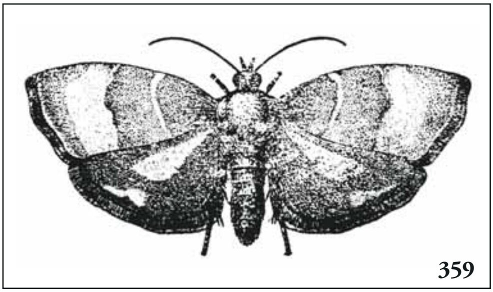

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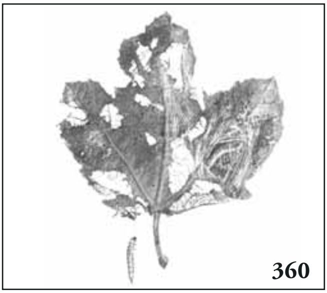

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Figs. 359-361. *Anthophila nemorana.* 359. Adult female (Cuscianna, from Silvestri 1943). 360.Fig leaf eroded by larvae and grown larva abandoning it (Sta. Firenze). 361.Erosion of fig leaves by larvae, and nests (shelters) of larvae (photo B.I.K.).

and has two black spots at its base, and the area of the ocelli dark. The pronotum is also light colored and bears black spots.

Pupa. Somewhat short and stout, brown, approximately 8 mm long, in a spindle-shaped cocoon near the leaf perimeter, or at another suitable site.

Host plants. The common fig *(Ficus carica),* edible and wild (caprifig), throughout the Mediterranean.

Life history and damage. The seasonal development of this insect has not been studied sufficiently. It is considered to have as a rule 2 generations per year in Italy and France, and perhaps a 3rd one in some other countries. It overwinters in protected places as a pupa

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in a cocoon on fallen leaves, or, according to Cusciana (1927) (as cited by Silvestri 1943), probably as an adult in protected places. The adults appear on the fig trees when the first young leaves appear. The female lays its eggs singly or in pairs on the upper leaf surface. The young larva selects a suitable site of the young leaf, where it weaves a fine white web under which, protected, it feeds on the upper epidermis and the parenchyma of the leaf, leaving usually intacts the veins and the lower epidermis. By the time it is fully grown, the larva may create more than one such nest-shelters in the same leaf or in neighboring leaves (Fig. 361). According to Cusciana (1927) each instar weaves a new nest. Pupation takes place usually on the leaves, in a dense, white spindle-shaped cocoon, usually at the folded leaf margin (Cusciana 1927). As the leaf grows, the lower epidermis is torn in the parts of the leaf where the parenchyma has been eroded by the larvae, and the leaf looks perforated in an irregular way (Fig. 360). The larvae can also erode fruits superficially, especially young fruits, when they are in contact with leaves or with other fruits. Yet, the main injury concerns the foliage. Generally, damage by this insect is not serious or frequent, and many natural enemies are reported for southern Italy. It is more frequent on single trees in gardens and yards. Perhaps irrigation creates conditions favoring this insect.

Control. In cases of heavy infestation, spraying the foliage is recommended in spring, against the young larvae of the first generation, with a contact or stomach insecticide of long residual action, before the larvae expand their web-shelters considerably, thus being protected from the spray liquid.

Blastophaga psenes **L. (Hymenoptera, Agaonidae)**, comm. **fig wasp, fig psenas**

Adult. The female is black or almost black, glossy, winged, and of an average length of 2.5 mm. The male is light brown or amber-colored, wingless, with the end of its abdomen long and narrow, and with short antennae (Fig. 362) (Ebeling 1959).

Host plants. Host of the fig wasp are the syconiums of the common fig tree, *Ficus carica* L. The fig wasp develops and perpetuates itself in the syconiums of the male or wild fig, or caprifig, but also enters and pollinates the syconiums of the edible fig. The wild fig tree produces three crops of syconiums, the caprifigs. The syconiums of the first

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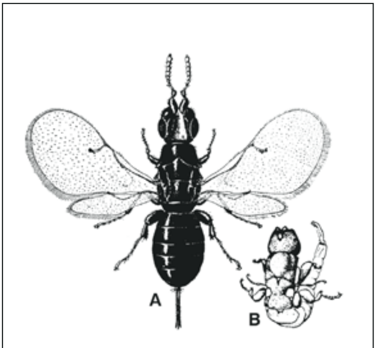

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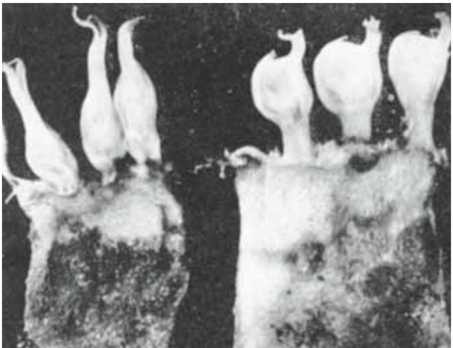
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Figs. 362-363. *Blastophaga psenes.* 362.Adult female left, and male right. 363.On the left long-style flowers of edible fig, and on the right short-style flowers of wild fig (Condit 1920, from Ebeling 1959).

crop of the year are known as fioroni, orni, or profichi. They develop in spring or summer, and bear female and male flowers. The syconiums of the second crop are known as forniti or mammoni. They develop in summer and ripen in late summer or in autumn. They contain many female flowers and usually, but not always, a few male flowers. The syconiums of the third crop, known as cratiri or mamme, develop in autumn, remain on the tree in winter, and ripen the following spring. They bear only female flowers, or also a few male ones (for details see Grandi 1920, 1962).

Life history. The fig wasp has 3 generations per year, as many as the crops of syconiums of its host, the wild fig tree. The syconiums of that tree, in addition to female, bear also male flowers. These syconiums are strongly protogynous. Their male flowers ripen a few weeks after the female ones, at approximately the time needed for the insect to complete a life cycle. This allows the adult female wasp, during its exit from the syconium it developed in, to take on its body surface fresh pollen and carry it to a syconium of the next crop in which it enters to oviposit. The insect overwinters inside the winter caprifigs (cratiri, mamme), and becomes adult in spring. After they mate, the females abandon the winter syconiums (cratiri), fly and enter the fioroni of the same tree or of neighboring wild fig trees, where they oviposit in their brachystylous female flowers (Fig. 363). According to Grandi (1929), it is the secretion injected into the fig ovule by the ovipositing wasp that causes transformation of the ovule

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into a gall and formation of a parthenogenetic endosperm which serves as food for the growing larva. The females of the next (spring) generation abandon the fioroni and search for suitable syconiums to oviposit. During their exit from the fioroni, the wasps rub against and carry pollen from the male flowers which are inside the ostiole (eye) of the syconium. This pollen the females carry on their body surface, and when they enter syconiums of the next crop, they pollinate their female flowers. Those flowers that will be pollinated and fertilized but not oviposited by the wasp will produce seeds, whereas those oviposited will produce wasps. During the search for syconiums of wild fig trees to oviposit, the female wasps enter also edible figs of nearby cultivated fig trees, which they pollinate. However, they cannot oviposit in the female flowers of edible syconiums because of their long styles (Fig. 363). During its entrance to the edible figs through the narrow ostiolar slits, the wasp loses its wings and flagellae of its antennae, therefore, cannot fly to other figs. It usually dies inside the edible fig, after having unsuccessfully searched for suitable female flowers to oviposit.

The syconiums of the edible fig tree usually do not have male flowers (Chandler 1957). In certain cultivars the syconium develops parthenogenetically, as in Mission and Kadota. In other cultivars, as are the Smyrna type, pollination is indispensable for the fruits to remain on the tree and ripen normally. In those cultivars it is the female fig wasp that brings the pollen from the fioroni of male trees. Where there are no male fig trees near cultivated ones that need pollination, caprification is needed and carried out. This consists in the timely collection of fioroni in June-July and in their placement, in some simple way, on the edible fig trees. The female wasps come out in a few days or hours from the fioroni and enter the neighboring edible figs, carrying the pollen. Therefore, the fig wasp is a useful pollinator insect, indispensable for certain of the best fig cultivars such as those of the Smyrna type, known as Calimyrna or Lob Injir and those of the White San Pedro type. Among the Greek cultivars needing pollination Anagnostopoulos (1939) mentions Kalamon, Vassilika, Argalastis and Kymis. The wasp may carry to the figs also undesirable microorganisms, which especially under humid weather or in humid areas cause acid or other rots. For this reason attempts have been made to create parthenocarpy by chemical substances. In certain cultivars the results were not so encouraging as for the growers to abandon caprification.

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In other countries, other species of fig (*Ficus*) have each its own species of pollinating insect of the order Hymenoptera. In addition to a review of the rerspective literature on the common fig, Galil (1977) describes in a lucid way the complex relationship between host plant and pollinating species of wasp in certain species of *Ficus* other than *carica.*

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Insects of walnut, chestnut, hazelnut, carob and mulberry

Homoptera

Empoasca decedens Paoli, Jassidae, [carob]
- *Metcalfa pruinosa* (Say), Flatidae, [hazelnut, walnut]

Aleyrodidae (whiteflies)

- *Dialeurodes citri* (Ashmead), Aleyrodidae, [hazelnut, mulberry]
- *Parabemisia myricae* (Kuwana), Aleyrodidae, [mulberry]
- *Siphoninus phillyreae* (Haliday), Aleyrodidae, (pomegranate)

Aphids

Callipterus juglandis Frisch-Goeze, Callipteridae, [walnut]
Chromaphis juglandicola (Kaltenbach), Callipteridae, [walnut]
Myzocallis coryli (Goetze), Callipteridae, [hazelnut]
Aphis craccivora Koch, Aphididae, [carob]
Corylobium avellanae (Schrank), Aphididae, [hazelnut]

Coccoidea (scale insects)

- *Aonidiella aurantii* (Maskell), Diaspididae, [carob]
- *Aspidiotus nerii* (Bouché), Diaspididae, [carob, mulberry]
- *Chrysomphalus dictyospermi* Morgan, Diaspididae, [carob]

Epidiaspis leperii (Signoret), Diaspididae, [walnut]
Epidiaspis piricola (Del Guercio), Diaspididae, (walnut)
Lepidosaphes ficus Signoret, Diaspididae, (pomegranate)
- *Lepidosaphes ulmi* (L.), Diaspididae, [walnut, hazelnut, carob]
- *Pseudaulacaspis pentagona* (Targioni-Tozzetti), Diaspididae, [walnut, mulberry]
- *Ceroplastes rusci* (L.), Coccidae, [mulberry]
- *Coccus hesperidum* L., Coccidae, [mulberry]

Eulecanium sp., Coccidae, [walnut]
- *Planococcus citri* (Risso), Pseudococcidae, [mulberry, carob]

Hemiptera

Deraeocoris flavilinea Costa, Miridae, [hazelnut]
- *Gonocerus acuteangulatus* Goeze, Coreidae, [hazelnut, chestnut, mulberry]
- *Carpocoris pudicus* Poda, Pentatomidae, [hazelnut]

Nezara viridula L., Pentatomidae, (pomegranate)

Thysanoptera (thrips)

- *Drepanothrips reuteri* Uzel, Thripidae, [hazelnut]

Coleoptera (beetles)

- *Anomala ausonia* Erichson, Scarabaeidae, [walnut]

Scobicia chevrieri Villa, Bostrychidae, [carob]
- *Sinoxylon sexdentatum* Olivier, Bostrychidae, [carob, mulberry]

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Xylomedes cornifrons Baudi, Bostrychidae, [carob]
Clytus arietis L., Cerambycidae, [hazelnut]
- *Oberea linearis* L., Cerambycidae, [hazelnut, walnut]
- *Apoderus coryli* L., Attelabidae, [hazelnut]
- *Byctiscus betulae* L., Attelabidae, [chestnut, hazelnut]
- *Rhynchites aequatus* (L.), Attelabidae, [hazelnut]
- *Curculio elephas* Gyllenhall, Curculionidae, [chestnut]
Curculio glandium Marsham, Curculionidae, [hazelnut, chestnut]
- *Curculio nucum* (L.), Curculionidae, [hazelnut]
Curculio robustus, Curculionidae (chestnut)
Coeliodes ruber Marsham, Curculionidae, [hazelnut]
Otiorrhynchus ovalipennis Bohemann, Curculionidae, [walnut]
Rhamphus pulicarius Herbst, Curculionidae, [hazelnut]
Strophosomus melanogrammus Forster, Curculionidae, [hazelnut]
- *Xyleborus dispar* F., Scolytidae, [chestnut, walnut, hazelnut, poplars]
Platypus cylindrus F., Scolytidae, [walnut]
Haltica quercetorum Foudr., Chrysomelidae, [hazelnut]

Diptera (flies)

- *Asphondylia* spp., Cecidomyiidae, [carob]

Lepidoptera

- *Lyonetia clerkella* L., Lyonetiidae, [chestnut]
- *Callisto avellanella* Stainton, Gracillariidae, [hazelnut]
Parornix avellanella Stainton, Gracillariidae, [hazelnut]
- *Phyllonorycter corylifoliella* (Haw.), Gracillariidae, (hazelnut]
Synanthedon codeti Oberth., Sesiidae, [walnut, chestnut]
Synanthedon vespiformis (L.), Sesiidae, [chestnut]
Parachronistis albiceps Zeller, Gelechiidae, [hazelnut]
- *Zeuzera pyrina* (L.), Cossidae, [walnut, hazelnut]
- *Cydia pomonella* (L.), Tortricidae, [walnut]
Epinotia tenerana Denis and Schiffermueller, Tortricidae, [hazelnut]
Eulia ministrana (L.), Tortricidae, [hazelnut]
Gypsonoma sociana Haw., Tortricidae, [hazelnut]
Laspeyresia amplana Hübner, Tortricidae, [chestnut, hazelnut]
- *Laspeyresia fagiglandana* Zeller, Tortricidae, [chestnut, hazelnut]
- *Laspeyresia splendana* Hübner, Tortricidae, [chestnut]
- *Pammene fasciana* L., Tortricidae, [chestnut]
Pandemis corylana F., Tortricidae, [hazelnut]
- *Ectomyelois ceratoniae* (Zeller), Pyralidae, [carob, walnut]
Ephestia calidella Guen., Pyralidae, [carob]
Ephestia figulilella Gregson, Pyralidae, [carob]
- *Hyphantria cunea* (Drury), Arctiidae, [walnut, mulberry]
Dasychira pudibunda (L.), Lymantriidae, [chestnut]
- *uproctis chrysorrhoea* (L.), Lymantriidae, [chestnut]
Orgyia antiqua L., Lymantriidae, [hazelnut]
- *Lymantria dispar* (L.), Lymantriidae, [chestnut, hazelnut]
Stauropus fagi (L.), Lymantriidae, [chestnut]

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Hymenoptera

- *Dryocosmus kuriphilus* Yasumatsu, Cynipidae, [chestnut]

***Gonocerus acuteangulatus* Goeze** *(G. venator)* **(Hemiptera, Coreidae),** comm. **hazelnut bug**

Adult. It is 12-15 mm long. On the dorsum it is brown, light or dark, with many black dots. The ventral side, the legs and the median dorsal part of the abdomen are green or yellow-green. The first antennal article is a little wider and shorter than the second, and a little longer than the third. The width of the female's abdomen is 5-6 mm. The pronotum is almost trapezoid, a little wider than the abdomen, with the posterior angles sharp and bending outwards and upwards (Fig. 364).

Egg. Almost ellipsoid, narrower in the two ends, at first bright golden yellow, and later (when the embryo has developed) brown.

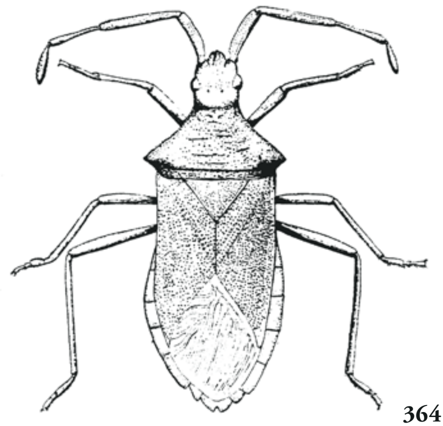
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Fig. 364. *Gonocerus acuteangulatus* adult female (Boselli 1932).

Larva. In the first-instar larva the head and thorax are brick-red and the abdomen green with a reddish spot where the odorous glands open. The grown, last-instar larva is 9.3-10.4 x 4.6-4.8 mm, ocher or whitish, with a pronotum similar to that of the adult.

Host plants. Hazelnut and other shrubs and trees, such as species of *Berberis, Rhamnus, Juniperus, Quercus, Rosa, Morus, Castanea, Buxus, Arbutus, Pistacia*. It causes considerable damage to hazelnuts.

Life history and damage. In Italy, it completes one generation per year. According to Boselli (1932), in southern Italy and Sicily it overwinters as adult in dense gramineous vegetation, in thick ivies which cover walls or tree trunks, or in thickets of *Erica, Cistus*

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and other plants. In the second half of May, the adults abandon their winter shelters, and go to nearby hazelnut bushes, especially to those setting fruit early, and having in late May fruits approximately 1,5 cm in diameter. They pierce and suck the fruits, but not other parts of the plant. During this feeding period, these bugs are found, singly or in small groups, on the apical and sunny parts of the plants. In the slightest danger they fly away. After June 10, the female deposits its eggs in groups of 2 to 15, the one near but not touching the other, mainly on the bracts surrounding the fruit, and exceptionally on the surface of the fruit or on leaves. Oviposition continues until early August. The first- and second-instar larvae pierce and suck the bracts and parts of the plant near the base of the fruits. From the third instar on, larvae and young adults pierce the fruit and suck the contents of the seed, until late August. Subsequently, they gradually abandon the hazelnut trees and go to chestnut trees if there are nearby. On chestnut they seem to be able to feed some more on the fruits. In late September they abandon the chestnut trees and go to the various shelters (above) to spend the rest of autumn and winter (Silvestri 1934).

In late May and June, the adults that have overwintered cause the “emptying” of fruits and “traumatic fruit drop” of hazelnut. Their rostrum goes deep, up to 5 mm, in the tender fruits and reaches the cotyledons whose development stops and the seed dies. The hazelnuts which are attacked in that period are distinguishable by a black or brown secretion at the site of puncture. Later, larvae and young adults of the new generation also pierce the fruit, causing necrosis of part or of the whole seed which shrinks, is deformed to a variable degree, becomes yellow or brown in part or in whole, and may become bitter or have some other, non typical taste. This injury of July and August can be caused also by other Hemiptera, such as *Palomena prasina, Carpocoris pudicus, Piezodorus lituratus, Rhaphigaster nebulosa, Dolycoris baccarum* and *Lygaeus pandurus*.

Control. When a considerable adult or larval population is detected, a spray, especially of the fruit-bearing parts of hazelnut is advisable, with a synthetic organic insecticide. Frequent examinations of the hazelnut shrubs in late May and in June is necessary, to detect the adults in time.

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Oberea linearis L. *(Cerambyx linearis, Saperda linearis)* **(Coleoptera, Cerambycidae)**, comm. **hazelnut and walnut stem borer, hazelnut cane borer**

Adult. The body is long and very narrow, 11-16 x 2 mm, generally black, except the legs which are ocher yellow. In the male the antennae are a little shorter than the body. In the female they are even shorter. The pronotum and the elytra are punctate and with a fine dark brown fuzz (Fig. 365).

Egg. Long and narrow, 3 x 0.6 mm.

Larva. It is apodous, and has the characteristic form of Cerambycidae. It is yellowish (according to some sources white), with the prothoracic shield brown, and a final length of 20 mm (according to some sources 22-25 mm) (Fig. 366). Paillot (1933) gives drawings of the adult, larva and pupa. Perdikis and Arvaniti (2014) gave photos of egg and young larva in its gallery in a walnut shoot.

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Figs. 365-366. *Oberea linearis.* 365.Adult. 366.Larva in its gallery in a shoot of hazelnut (photo B.I.K.).

Host trees. Hazelnut and walnut. Paillot (1933) mentions that *Ostrya carponifolia, Alnus* sp. and *Ulmus* sp. are also infested. In other countries hazelnut is considered the host of preference. There are reports that walnut trees near wild hazelnut trees, often suffer serious damage. In Greece this insect occurs in many areas, on both walnut and hazelnut.

Life history and damage. On hazelnut it completes one generation every 2 years in southern and central Europe, and one every 3 years

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in colder regions (Balachowsky 1962). Semivoltinism on hazelnut agrees with unpublished observations by the senior author, who found overwintering larvae in central northern Greece either fully grown, or at a distinct, much earlier, instar, indicating that some larvae were in their first and some in their second and last winter. On the other hand Anagnostopoulos (1939) who studied it on walnut in Greece, mentions one generation per year on that tree. However, we feel that univoltinism on walnut in Greece, needs substantiation with specific serial samplings and observations.

On hazelnut, according to Balachowsky (1962) it passes the first winter as a relatively young larva, and the second winter as a fully grown one. It pupates in spring, in the larval gallery in the stem of the tree. The adults emerge in late May and in June. The female with its mandibles makes a cut in the bark, at 10-15 cm from the tip of a shoot, and lays an egg. The young larva at first bores a semicircular gallery vertical to the shoot axis. This gallery is at a relatively small depth and extends from 2/4 to 3/4 of the perimeter of the shoot. Along this gallery the bark surface is raised and is lighter in color. This superficial gallery gradually causes the death of the shoot, which easily breaks. Subsequently, the larval gallery goes deeper, and finally follows the shoot axis and is descending, directed towards the base of the shoot. The larval excreta are discarded to the outside through small holes the larva makes at various heights of the shoot. After overwintering, the larva continues its development and boring its gallery in the warm season of the following year. It completes its growth in autumn, and overwinters. In hazelnut shoots and twigs the larval gallery in the first year reaches 40-60 cm and is descending, whereas in the following spring it becomes ascending (Balachowsky 1962 and references therein). This larval behavior is in general agreement with the information given by Paillot (1933). Paillot (1933) states that after having laid an egg, the female girdles the shoot a little above the oviposition point. In the regions of Europe where the life cycle is completed in 3 years, the first winter the larvae remain in various twigs. The next spring they move to second-year-old twigs and continue eroding them (Paillot 1933). They achieve full growth in the spring of the 3rd year.

On walnut, seasonal development as reported by Anagnostopoulos (1939) for the Aetoliko area, a coastal part of western central Greece, is as follows: The formation and emergence of adults from the shoots takes place in May to early June. After a feeding period

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of a few days, during which they cause erosions of a limited extent to the new vegetation (leaves and bark of shoots), the adults mature sexually, mate, and the female lays its eggs, one per shoot, on the bark, a few centimeters from the tip, or on the pedicel of a fruit. It prefers shoots which bear fruits and are not vigorous. If it oviposits on a vigorous shoot or twig, the female with its mouth parts causes a perimetric complete or partial erosion of the bark at approximately the middle of the shoot. This girdling weakens the shoot and seems to favor the development and survival of the larva. Hatching takes place in late May to mid-June. The larva penetrates the shoot in which it bores an ascending or descending gallery. When the egg is laid on the fruit pedicel, the gallery is bored in the pedicel and in some cases is extended to the fleshy mesocarp, and further to the shoot. Paillot (1933) in France did not observe on walnut the transverse cut made by the female above the oviposition point. In the Oenoe area of Attica (eastern central Greece), Perdikis and Arvaniti (2014) observed a heavy infestation of walnut trees by this beetle. The adults in 2012 and 2013 appeared there in late April. In oviposited shoots the female eroded in part the stalk of a leaf which withered and remained hanging. This usually made the detection of infested shoots easy. At the oviposition site the female made a 5-7 mm-long superficial oval erosion of the bark.

The larval galleries in the pedicels of walnuts cause the drying and early drop of those fruits in July. Galleries in shoots and twigs cause dying of the part of the shoot and fruits above the gallery. Therefore, we have loss of fruits of the year, of flower buds of the next year, and of a low or high percentage of shoots, therefore of foliage of the tree in general. When the insect's population is dense, as observed decades ago in Aetoliko and the island of Andros, the yield of walnut is almost annihilated and walnut growing becomes problematic (Anagnostopoulos 1939). Damage to hazelnuts can also be such as to require control measures.

Control. On hazelnut the best control method is to remove and destroy the infested dry shoots and twigs from autumn until early spring, before adult beetles emerge from them. Instead of destroying them, we could place, in or near the orchard, the dry shoots and twigs in a cage with wirescreen of the proper mesh, allowing the escape of the beetle's parasites but not of the beetles. Another measure is to spray the shrubs when the adults appear (late May to early June), with

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an organic contact insecticide of long residual action, but if possible selective, in order not to eliminate the effective natural enemies of this stem borer. On walnut where, because of the height of the trees, it usually is hard to remove the infested twigs, insecticidal sprays are relied upon. It is necessary that the period of adult activity and oviposition be determined in each area, so that control be effected with the fewest sprays possible. Perdikis and Arvaniti (2014), for the area they worked in, suggest to check the walnut trees in late April and early May for signs of oviposition, and spray promptly. When removal of infested (withered) shoots and twigs is possible, Anagnostopoulos (1939) suggests that this be done in July, so that further injury towards the base of the twig and destruction of side shoots be prevented. He also mentions that in late March, when new growth of walnut has started, the shoots with dead tips are easily seen.

Apoderus coryli **L.** (*A. avellanae, A. collaris, A. gibbicollis, A. superbus*) **(Coleoptera, Attelabidae)**

Adult. It is 6-7.5 mm long and of variable color. Head, prothorax and elytra are usually red, but also may be partly or wholly black. It is easily recognizable because of its pedunculate head (Balachowsky and Hoffmann 1963).

Host plants. Hazelnut, and species of *Betula, Fagus, Quercus* and *Salix.* It occurs in all the Palaearctic region, from western Europe to Japan. It is injurious to hazelnut in Europe.

Life history. The information is limited. According to Balachowsky and Hoffmann (1963), the overwintered adult comes out in April-May and feeds on the foliage, buds and young shoots of host trees, and especially on the female flowers of hazelnut. The eggs are laid in the leaves which the adult female rolls longitudinally to form a cigar-like cylinder. The larva lives and pupates in the leaf cylinder it was born in. The adults emerge in June-July from the leaf cylinders that have usually fallen to the ground. Second-generation eggs are laid in July-August.

Curculio elephas **(Gyllenhall)** *(Balaninus elephas, B. mastodon)*

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(Coleoptera, Curculionidae), comm. **chestnut weevil, balanine of chestnuts**

Adult. It has the characteristic shape of the balanines (see *Curculio nucum*, below). The body proper (except the rostrum) is oval, quite oblong, approximately twice as long as wide. The rostrum is especially slender and long, equal to or longer than the body proper in the female, and quite shorter in the male. Total body length 6-10.5 mm. Color light grey-brown, or grey, or light brown. The tip of the elytra has a fuzzy margin. Coutin (1958) mentions that adults derived from larvae that grew in glands (fruits) of the oak *Quercus ilex* are very small, almost half as long as those from larvae that grew in chestnuts.

Egg. Ellipsoid, white, with a smooth and soft chorion, and 0.4-0.5 x 0.3-0.4 mm.

Larva. Apodous, white, with a brown head, with the body curved, and a final length of 7-12 mm. (Fig. 367).

Host trees. Chestnut and various species of oak, deciduous and evergreen (Coutin 1958). It often damages chestnut.

Fig. 367. *Curculio elephas.* Larva and a larval exit hole in a chestnut (photo B.I.K.).

Life history and damage. It has one generation per year. However, certain individuals of the population may complete their life cycle in 2 or 3 years. It overwinters as fully grown larva in the soil, in a cell that the larva makes. It pupates in late spring to early summer, and becomes adult from early to late summer. The adult weevils feed for a number of days on fruits and buds of host trees. These feeding holes are done usually at the basal part of fruits and cause their sickliness, weakening, reduced size or spoilage. After feeding and maturing sexually, the adults mate and the females start laying

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eggs. Oviposition lasts the whole September, but is more intense the first half of that month. The female lays its 25-50 eggs, one in each cupule (spiny chestnut fruit), after boring with its rostrum an oviposition hole. This hole is bored usually at the basal half of the cupule. The same female seldom lays 2 or 3 eggs in the same fruit, but other females may lay eggs in an already oviposited fruit. In such cases, as many as 8-10 larvae have been observed in a single fruit. In glands (fruits) of oaks, much fewer larvae are observed per fruit. Incubation lasts approximately a week. The young larva bores a gallery in the seed (chestnut) consuming its inner part. After completing growth, in 30-45 days, the larva opens an exit hole (Fig. 367) in the seed, which meantime has fallen to the ground, and enters the soil. There, at a depth of usually 5-20 cm, it forms a cell by compressing and gluing the surrounding soil. In that cell it remains in dormancy until the following spring, or the spring of the second or third year. In western Crete, substantial populations of adult weevils were observed mainly in early September and eggs on fruits mostly the first half of September (Kalaitzaki et al. 2005).

The percentage of infested chestnuts varies with the cultivar and may be considerable. Coutin (1958) mentions, for a certain area of France, 90% infestation in the cultivar “Bourgeois”, and only 1.5% in the “Marron du Gard”. It seems that the degree of resistance of chestnut to this weevil depends on the density and pattern of spines of the cupule. The more dense and entangled the spines are, the less the percentage of infestation. High percentages of infestation of chestnuts have been reported also in Hungary by Bürges and Gál (1981), who studied the life history of the weevil in that country. In a two-year survey in five localities of western Crete, the percentage of fruit infestation reached 50% in early chestnut cultivars, but only 10% in late ones (Kalaitzaki et al. 2005).

The larvae of *C. elephas* develop in chestnuts at approximately the same season with the larvae of the Lepidoptera *Laspeyresia splendana, L. fagiglandana,* and *Pammene fasciana,* which also infest the glands of oaks, in addition to chestnuts. Therefore, neighboring oaks may play some role in the density of populations of those insects on chestnut trees.

Control. A high percentage of larvae abandons the chestnuts after their natural fall off the trees. Therefore, the timely collection and giving to farm animals of infested chestnuts reduces the larval population, and in certain areas may be a sufficient measure of

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control.

Despite the adult being susceptible to many organic synthetic insecticides, the great height of chestnut trees and the whole structure of chestnut forests makes effective control by insecticides difficult. In western Crete, an insecticidal application in mid-August against both the weevil and the moth *L. splendana* is suggested for early cultivars, whereas for late cultivars one in mid-August against the moth, and a second in the first decade of September against the weevil (Kalaitzaki et al. 2005).

In a recent survey of insects infesting the fruit of chestnut in Greece, the larvae of *Curculio glandium* Marsh. and *C. robustus* were also found in certain samples (D. Avtzis et al. 2011).

***Curculio nucum* (L.)** *(Balaninus nucum, B. gulosus)* **(Coleoptera, Curculionidae)**, comm. **hazelnut weevil, hazelnut worm**

Adult. The body proper (except the rostrum) is almost spindle-shaped or almost rhomboid, grey or light brown, and 6-9 mm long (Fig. 368). La Ferla (1941) describes in detail the adult and larval morphology. He gives 6.5-7.5 mm the length of adult females he studied in the Avellino region of Italy. The rostrum is yellow-red, slender, curved downwards, and in the female almost as long as the body, while in the male shorter. The cuticle is black, but covered with a brown-yellow, light brown, or grey fuzz. Thus, the elytra usually look greyish brown, with light brown spots. In the posterior half of their touching line the elytra have a raised margin bearing a bunch of short hard hairs. The legs are light brown. The apical three antennal segments are hairy and distinctly wider than the rest.

Egg. Shiny white, 0.77 x 0.5 mm.

Larva. It is apodous, quite stout, curved, narrower in the two ends, yellowish white, with a yellow-green or yellow-red head, and black mandibles. Fully grown it is 4.5 mm long (according to some sources 6-7 mm).

Host tree. Hazelnut.

Life history and damage. It is believed that in Greece it completes one generation per year, and that certain individuals may complete their life cycle in 2 or 3 years. It overwinters as grown larva in a cell in the soil. It pupates and becomes adult in that cell in spring. According

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Figs. 368-369. *Curculio nucum.* 368. Adult (Calwer 1893). 369.Upper right, larva in an eroded hazelnut. Bottom, exit hole of a grown larva on the side of a hazelnut A.U.T.).

to Anagnostopoulos (1939), in the Aghia, Thessaly area of central Greece, pupation takes place in late March, and the adults emerge from the soil in early April. They then go to such trees as cherry, plum, peach, quince and pear, where they eat the flesh of young fruits. This erosion of fruits of Rosaceae may cause deformation or even destruction of the fruits. This period of feeding of the weevils on trees other than hazelnut, lasts from early April to early May, in Thessaly. Subsequently, in May and early June, the weevils fly to the hazelnut shrubs, where they continue feeding on young fruits and leaves. Injury to the leaves is unimportant, but the feeding holes on fruits cause their drop. This fruit drop occurs at the time of the natural drop (physiological, or June drop) of hazelnut, and often goes unnoticed. Yet, it may concern a considerable percentage of the yield. The feeding punctures (holes) continue also during the weevil's oviposition period, and are often accompanied by the development of fungi around the holes. The fungi enter the fruit and spread to the seed, resulting in its destruction and in a second batch of fruit drop in July-August. This relatively late fruit drop, added to the earlier one, raises the percentage of fruits destroyed by feeding holes to considerable levels.

The adults are active during the day and especially on relatively warm and sunny days. After the feeding period, the weevils mature sexually, mate, and oviposit in the hazelnuts. The female bores with its rostrum an oviposition hole, through the bracts and the pericarp, usually at the basal 1/3 of the fruit. It prefers fruits of 11-12 mm in diameter, the pericarp (shell) of which is still tender, so that it can

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be eroded by the female's mandibles, which are located at the tip of the rostrum. After completing the hole, the female turns its body by 180° and introduces an egg. As a rule one egg is layed per fruit, but exceptionally 2 or 3 may be laid. Only one larva develops per fruit normally, and very seldom two. In Thessaly oviposition takes place in May. The larva bores a gallery first in the soft perisperm, then enters the seed which it feeds on (Fig. 369). In contrast to the feeding holes the adults make, the oviposition holes are not infected by fungi and heal quickly. On the inner surface of the pericarp where the egg is laid, a gall-like small tubercle is often formed, due to the reaction of the plant tissues. In Thessaly, the larva completes its growth in late July to mid-August. It then opens a hole, approximately 2 mm in diameter, in the pericarp (Fig. 369) which by that time has hardened, and falls to the soil where at a depth of 10-25 cm it makes a cell by compressing the soil and using a special secretion. In that cell it remains dormant until the following spring, or the spring of the 2nd or 3rd year. The infested fruits drop at approximately the time the larva inside them completes growth. Thus, some hazelnuts drop before the larva abandons them.

Three-year records by Martin (1949) in the Tarragona province of Spain showed an adult behavior similar to that in central Greece, but a different number of generations per year, the cycle being semivoltine, and for part of the population even longer. According to Martin's graph, the adults in Tarragona were seen on various fruit trees and hazelnut from early April and mostly in May-June until mid-July. In April, May and June they fed on various trees such as pear, apple, peach, kaki, then on hazelnut. During that period they may pierce and feed on young hazelnuts which soon drop. Such injury may be substantial in certain localities and years. Oviposition occurred from early June to mid-July. It was maximum in mid-June on an early cultivar and in late June on a late cultivar. Larvae grew in the hazelnuts from early June to late August. Fully grown larvae were observed from the second half of July and mostly in August. They abandoned the fruits and entered the soil to overwinter. Part of the larval population pupated the next June, while the rest remained in the soil as larvae for a second or third winter. In all three years pupation took place in June and was massive. The adults are formed soon after pupation. Some of them remain in the pupal cell until April, and some emerge from the soil in mid-September and overwinter in protected sites in or near the grove. Therefore, the life

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cycle in Tarragona was completed in 2, 3, or 4 years, according to Martin (1949).

For the seasonal development of this insect in central Italy see Paparatti (1990) and Pucci (1992). Pucci (1992) reports that in northern Latium (central Italy), in 1987, eggs were laid mostly in July, L1 covered the period from mid-July to late August, L3 from early to mid-August, L4 from mid-August to mid-September, and galleries abandoned by the fully grown larvae from mid-August to late September. In 1988 seasonal development was slightly earlier, eggs from late June to mid-July, L1 early July to mid-August, L3 late July to mid-August, L4 in August, and abandoned galleries in August and early September. Adults were captured mostly from late May to early or mid-July, depending on the year, and the peak of egg-laying occurred in late June to early July.

Damage by this weevil may be serious in certain areas. Isaakides (1936a) mentions that in villages of Aghia, Thessaly, in certain years 80% of hazelnuts was damaged by larvae. This damage, in addition to that caused by the feeding holes of adults, results in a considerable reduction of the yield. Anagnostopoulos (1939) considered *C. nucum* as the most important animal pest of hazelnut in Greece. It is believed that late-fruiting cultivars having small and hard fruits are infested less than other ones. According to Pucci (1992), in central Italy feeding injury by adults caused little damage, yet one egg-bearing female per plant corresponds to more than 10% egg-infested fruits. He estimated the total damage at 30-40% of the yield.

Control. Shaking the hazelnut shrubs in the first morning hours and collecting the falling adults on a cloth underneath is a good measure for relatively small plantations. This procedure must be repeated as needed, even every day, during the period of adult activity. In central Italy, 3 sprays are usually applied, in early, mid- and late June, with organic contact insecticides (Paparatti 1990). In Greece, the Ministry of Agriculture used to recommend one spray in approximately late May, when the hazelnut seed (embryo) has the size of a sesame seed, with an organophosphorous or other proper insecticide (Anonymous 1973). Martin (1949) recommended to treat the trees with a contact insecticide as soon as the adults appear on them, in April or May, and to repeat it if necessary.

In Turkey, Hovasse (1930), in addition to *C. nucum* and *Xyleborus dispar,* recorded on hazelnut the beetle *Haltica quercetorum* and the moth *Parornix avellanella*.

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***Xyleborus dispar* F.** *(Anisandrus dispar)* **(Coleoptera, Scolytidae)**

Adult. In this species the male is distinctly smaller than the female. The female is 3.2-3.6 mm long, and has an almost black and very convex pronotum, which is granular in its anterior half. The elytra are almost black with brownish reflections and are convex up to their apex (Balachowsky 1963). According to Della Beffa (1961) it is black, with reddish legs and antennae (Fig. 370). The male is 1.8-2.1 mm long, and has a pronotum less convex than that of the female, totally smooth, and elytra as long as wide. The males are fewer than the females, and do not fly.

Host trees. This bark beetle is polyphagous. It infests broadleaf trees, such as Rosaceae, Fagaceae and others. According to Balachowsky (1963) it prefers fruit trees of the Rosaceae and forest trees with soft wood (willows, *Betula verrucosa, Alnus glutinosa)*, and less so trees with hard wood such as oaks, chestnut and walnut. According to Della Beffa (1961) it infests especially chestnut and other Fagaceae.

Life history and damage. In central and southern Europe, it completes one generation per year. It overwinters as adult in dormancy in galleries in the trunk and branches of host trees. Mating seems to take place before the female completely abandons the gallery to fly to a new tree. The adult females come out of the galleries in approximately late April and disperse. In May they bore galleries in new trees. The entrance gallery is approximately vertical to the axis of the trunk or branch and 5 mm or longer (Della Beffa (1961). Left and right of the entrance gallery, on a plane vertical to the axis of the branch, it bores two curved galleries, parallel to the annual rings of the tree. From each of these two galleries, the female bores vertical galleries, parallel to the fibers of the wood and the axis of the branch, approximately 2 cm long, in which it oviposits (Fig. 370). Same as in other species of the same subfamily (Platypodinae), the female prepares a mixture of wood borings and feces, which forms the substrate for the development of a certain fungus which constitutes the food of the larvae (Fig. 370). The conidia of the fungus either are in the female's feces, or are on its head externally, or in its fore intestine and the female regurgitates them when preparing the substrate for the fungus. The mycelium spreads in the galleries and makes their walls dark. *X. dispar* infects its galleries

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Figs. 370-371. *Xyleborus dispar*. 370.Adult female and eggs in its gallery. The whitish myceleum on the walls of the gallery can be seen (photo H. Hoepli). 371. Galleries full of young adults (black) (photo A. Staub).

with the fungus *Monilia candida* or with *M. antennata* (Della Beffa 1961, Balachowsky 1963). The larvae do not bore galleries, but grow feeding on the fructifications of the fungus, and perhaps also on the fungal mycelium which develops on the walls of the gallery. Perhaps the larvae also imbibe plant sap. They complete their growth and pupate mainly in June or July, and become adults in July-August. The adults remain in their galleries until the following spring (Fig. 371).

According to Balachowsky (1963), the injury to fruit trees is serious, and often results in the death of the tree. In chestnut trees of Arkadia (Peloponnese) and Eurytania (west central Greece), Tzamos et al. (1981) found in chestnut trees infested by this insect, fungi of the genus *Ceratocystis* which caused withering and death of limbs and branches. There was a strong brown discoloration of the wood in the insect's galleries. In chestnut trees of the Daphni Kozanis area of northwestern Greece infestation by this insect was ascertained in 1997 (N.T. Papado[poulos, unpublished observations and personal

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communication).

Control is difficult, because during most of the year the insect is inside the tree. Experiments on apple trees in Switzerland (Mani et al. 1990) showed that endosulfan at a concentration of 0.75% was the only somewhat effective of the insecticides tested at the beginning of the period reproduction galleries are bored (first captures of adult females in traps). Spraying the trunk with an insecticide is recommended in that country only in young trees, especially 2-year-old, which are injured the most by this insect. Following of the female adult population is done with red color traps of the Rebell type, to which a special bottle with ethanol is attached. These traps, at a density of ten traps per hectare, can be used also for mass trapping the females (Mani et al. 1990).

Asphondylia **spp. (Diptera, Cecidomyiidae)**, comm. **carob gall midge**

Up to 1975, it was believed that, in countries around the Mediterranean, small carob pods are infested by the gall midge *Asphondylia gennadii* (Marchal), known also as *Eumarchalia gennadii, Schizomyia gennadii, or Cecidomyia ceratoniae,* which had as host plant only the carob tree *(Ceratonia siliqua).* However, the work of Orphanides in Cyprus (Orphanides 1975) has shown that the carob tree is the winter host of gall midges which in spring, summer and autumn infest various other plants. Until studies on this subject are complete, Orphanides separates the “carob gall midges complex” in three races or sibling species, which are not separable morphologically. Temporarily, he named each race after the common name of its usual secondary host-plant, as: caper gall midge, pepper gall midge and gall midge of *Urginea maritima.*

Adult. It is black and 5 mm long. The head, thorax and abdomen are covered with long grey hairs. The antennae have 14 articles of which the two apical ones are spherical. The mandibular pulps have two articles (Avidov and Harpaz 1969). When at rest, the abdomen is directed upwards (Orphanides 1975).

Larva. The young larva is cylindrical and almost transparent. However, it soon becomes light yellow or orange. The second-instar larva is also cylindrical, while the third (last) one is narrow on the sides and has on the prosternum the spatula and on the tip of the

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abdomen a small plate dorsally, which are characteristic of many gall midges.

Pupa. At first it is light brown, and later darker. It is at a whitish site in the carob pod.

Host plants. Host of the winter generation is the carob tree, which suffers the most injury. In Cyprus, the warm season of the year (spring to autumn) hosts of this insect are species belonging to different plant families, such as *Solanum tuberosum, Capparis spinosa, Eruca sativa, Sinapis* spp., *Urginea maritima, Asphodelus fistulosus, Hypericum crispum* and *Capsicum annuum.*

Life history and damage. It has 6 or 7 generations per year in Cyprus, and at least 3 in Israel. According to Orphanides (1975), its life history in Cyprus is the following: It overwinters as a first-instar larva inside the young carob pods. The main period of bloom and fruit set of carob there, lasts from August-September to December. The females of the last (summer or autumn) generation introduce their eggs singly in the young pods, mainly in October-November. Usually one, and more seldom 2 or 3 eggs are introduced per pod, especially when the pod is 5 mm long. The larva is a fruit borer. It eats the fleshy part of the pod, and its presence creates a tumor on the pod. Larval growth continues until spring. When its growth is complete, the larva approaches the surface of the pod and opens a hole, so that the adult may later come out. In its gallery near that hole it pupates. A little before the adult emerges, the pupa pushes its body outwards. Thus, when the adult emerges, part of the puparium (pupal skin) protrudes to the outside of the pod. Adults are formed in April or May. They oviposit on the herbaceous plants (alternative hosts) mentioned above. By autumn, 5 to 6 generations of the midge are completed in the pods, in other fruits, or in closed flowers of those herbaceous host plants. In October-November the adults of the last generation return to carob where they oviposit on the young pods. A small percentage of the penultimate generation may also oviposit on carob. In such a case a second partial generation may be completed on carob. The infested pods do not develop normally. Usually they shrink, twist, and drop prematurely.

Among the natural enemies of the midge, the parasitic Hymenoptera *Tetrastichus brevicornis* (Panzer) and *Eurytoma dentata* Mayr are reported.

Control. Because of the low market price of carobs, control measures

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are usually not justified. Certain authors recommend the timely collection and destruction of infested pods.

***Laspeyresia fagiglandana* Zeller** *(Cydia grossana)* **(Lepidoptera, Tortricidae)**, comm. **chestnut carpocapsa**

Adult. It resembles the light-colored form of *Laspeyresia splendana,* but can be distinguished by the coloration of the wings, the smaller size, the abundance of curved hairs on the lobes of the ovipositor, and the absence of small teeth on the phallus.

Host trees. Mainly *Fagus sylvatica* and *Quercus ilex.* Its presence in fruits of other species of *Quercus*, as well as in chestnuts and hazelnuts has also been reported.

Life history and damage. It seems to complete one generation per year. The larva develops in August-September in the fruits of *Fagus* spp. According to I.D. Ioannidis (personal communication), in the chestnut groves of the mountains Pelion and Kissavos, the presence and captures of adults in traps lasts from early July to mid-September, with a maximun between 10 and 15 August. The collection of chestnuts in those areas begins approximately in mid-September. In various areas of Greece (Pelion, Kissavos and elsewhere), Ioannidis determined in the decade 1969-1979, a serious infestation of chestnuts by this insect. On Pelion and Kissavos the damage to chestnuts was much more serious than that caused by *L. splendana,* but less serious than that by *Pammene fasciana.* For control measures see *Laspeyresia splendana,* below.

***Laspeyresia splendana* Hübner** *(Carpocapsa splendana, Cydia splendana)* **(Lepidoptera, Tortricidae)**, comm. **chestnut carpocapsa, chestnut worm**

Adult. It has a wing span of 13-19 mm. Its size varies with the species of host. It has been ascertained that individuals that as larvae grew in chestnuts are as a rule distinctly larger than individuals grown in oak glands, and especially those of *Quercus ilex.* The general shape, appearance, and spots of the forewings resemble those of the respective wings of the codling moth of apples, *Cydia pomonella.* This means that in the typical form, which is known as light-colored, approximately the basal third of the forewings of *L. splendana* is

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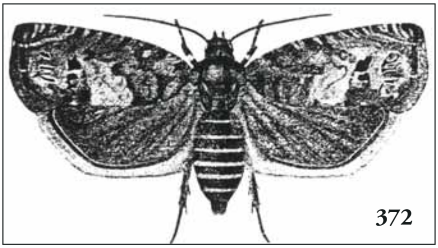

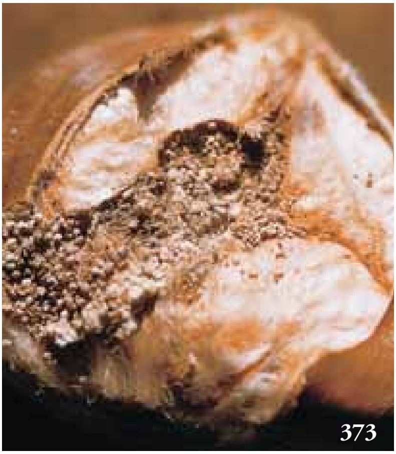

Figs. 372-374. *Laspeyresia splendana.* 372.Adult (Russo, from Silvestri 1943). 373. Chestnut eroded by a larva, and larval feces. 374.Larval exit hole (A.U.T.).

darker, the median is lighter, and the apical third darker, with the characteristic spot (*speculum*) near the anal corner (Fig. 372). Yet, it differs in that on the generally grey or grey-brown forewings: 1) the darker basal part is pointed towards the middle of the wing, 2) the median lighter part forms a corner, approximating the figure 7 (on the right wing), 3) the speculum is bordered by two silver-colored zones and includes 5 black lines, and 4) along the border of the fore margin (costa) the comma-like lines are clearly seen. The hindwings are brown or light brown, with light-colored fringes. In the form known as dark-colored, which has been described as a separate species (*L. reaumurana),* the forewings are uniformly dark brown without their basal part differing distinctly from the rest, and the comma-like lines along their front margin are discernible throughout its length. Also the *speculum* is also clearly seen (Bovey 1966).

Larva. The fully grown one is 15 mm long. It is whitish or pink, with light red-brown head and prothoracic shield.

Host trees. This moth is oligophagous. The larva feeds on only

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chestnuts and glands of all species of oak. Beyond the northern limit of distribution of chestnut, it infests only oaks.

Life history and damage. It has one generation per year in Greece, France, Switzerland, and generally in all the region of its distribution. In France and Switzerland, where its life history has been studied considerably, it overwinters as a grown larva in the soil, in a cocoon, at a relatively small depth. On the surface of the cocoon are stuck soil granules which make difficult the distinction of it from the surrounding soil. The larva pupates in July, and becomes adult 20-30 days after pupation, that is mostly in August. In southern Switzerland, the presence and activity of the adults lasts approximately one-and-a-half month, with most adults being observed from mid-August to mid-September. At that time, the chestnuts are already formed in the cups and have a diameter of 2-3 cm. The female mates and oviposits for approximately 10 days, starting the first days after mating. According to some authors it lays 40-50, and according to some others 150 eggs on the average. The eggs are laid singly on either surface of leaves that are near fruits, and usually near the midvein of the leaf. Incubation lasts 1-2 weeks. The young larva wanders on the foliage without feeding, until it meets a suitable fruit where it enters. It usually enters after opening a hole in the basal part of the fruit. Subsequently, it crosses the pericarp at the part known as scar, and after boring a gallery 3-5 mm long, it enters a seed where it grows at the expense of the cotyledons. Its granular feces are left behind it in the gallery (Fig. 373). Larval growth lasts approximately one month. In Greece, according to Anagnostopoulos (1939), the larvae grow in chestnuts or in oak glands from August to October. In western Crete too, chestnuts injured by the larvae were found from August to October (Kalaitzaki et al. 2005). Although more than one young larva may enter a chestnut, usually only one, and very seldom two develop normally. This is probably due to cannibalism. However, it is possible that a larva of *L. splendana* co-exists in the same chestnut with one or two larvae of the weevil *Curculio elephas.* When fully grown, the larva abandons the chestnut after opening a relatively small hole, 1.5 mm in diameter, through which, with great effort its twice that diameter body passes (Fig. 374). Infested chestnuts usually drop early, before the larvae complete their growth. Then, if given the time, the larvae will complete growth in the fallen chestnuts, then will enter the soil.

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L. splendana is a serious enemy of chestnuts in many countries. The infested (wormy) chestnuts are lighter than the uninfested ones, often shrunk at the disc, and many have the exit hole of the larva. Generally, infested chestnuts are unsuitable for consumption or for the market. In a survey of chestnut insect pests in five localities of western Crete in 2003 and 2004, adults were trapped from late July and peaked in mid-August (Kalaitzaki et al. 2005). Fruit infestation was from 4 to 22.5% from mid-August through October, depending on the locality and sampling date. The chestnut weevil was the main pest of chestnuts in that area of Crete (see above).

Control. The nature of chestnut groves and forests, makes control of chestnut pests generally difficult. Control measures against *L. splendana* are usually cultural, although in certain specific cases chemical control can also be applied. Timely collection and destruction of infested chestnuts that drop early or are sorted as infested at harvest. Destruction by burning or giving to pigs or other farm animals is the usual procedure. Also, it is recommended at harvest not to leave piles of chestnuts on the ground for days, but to transfer them immediately to special rooms or to put them in holes in the ground. The holes must be deep enough so that the burried fruits are at such a depth that neither the larvae nor later the adults may escape. On low or medium height trees (up to 5-6 m) the use of insecticides proved satisfactory. The time of insecticide application is determined by following the emergence of adults from the soil. The sprays aim at killing the moths before they lay most of their eggs. There are attractive sex pheromones on the market for both *L. splendana* and *L. fagiglandana.* In Italy, they have been used to follow the moth populations to determine when to spray, for mass trapping of the moths, and also for control with the mating disruption method. The results were encouraging (Angeli et al. 1997).

***Pammene fasciana* L.** *(P. juliana)* **(Lepidoptera, Tortricidae)**

Adult. It has a light brown body color and a wing span of 15-18 mm. The forewings are lead-grey in their basal part, with grey cross lines. In the middle and towards the posterior margin of the forewings there is a relatively large whitish spot.When the moth has its wings closed, the whitish spots of the two forewings form a large, almost

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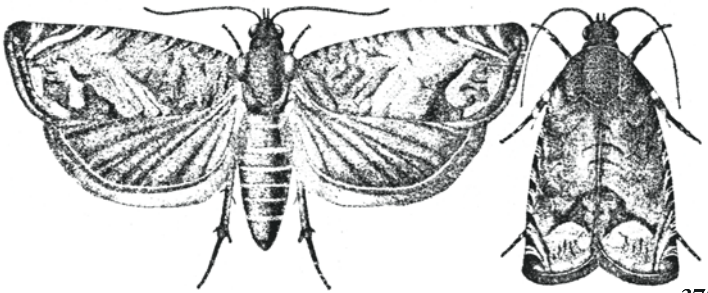
circular spot at about the middle of the wings. The speculum is characteristic and has 2 grey side stripes, which enclose a brownish area with 4 black small lines. Further, towards the base of the wing, there are 3 small black spots. Along the anterior margin there are many dark spots in the shape of a comma, which are separated by light-colored spaces (Fig. 375). The hindwings are grey-brown (Bovey 1966, Baggiolini 1967). This moth is distinguished from *Laspeyresia splendana* by its more vivid coloration, and the patterns of the forewings.



375

Fig. 375. *Pammene fasciana* adult (Russo, from Silvestri 1943).

Egg. Whitish, planoconvex, elliptic or almost circular when seen from above.

Larva. At first it is whitish or pink, later becoming light hazelnut brown, with the head, prothoracic shield and anal comb brown. The neonate larva is 1.5-2 mm, and the fully grown one 10-13 mm long (Bovey 1966, Baggiolini 1967).

Host trees. Mainly chestnut. However, the larva can develop also in oak glands and in fruits of *Acer* spp. (Bovey 1966).

Life history and damage. It completes one generation per year. According to Baggiolini (1967), it overwinters as a developed larva, in a cocoon, in protected sites of the bark of the host trees. In southern Switzerland, northern Italy and Spain, the adults are formed in June-July. The female oviposits on the upper leaf surface. The young larva goes to a young fruit (cup), enters it through a hole it makes at its base, and eats the young chestnuts (seeds). The presence of a larva inside a fruit is concluded from its feces which it pushes

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out and unites with silk threads. The larva completes its growth in approximetely 40 days in southern Switzerland. It then abandons the fruit and reaches a protected site of the bark of chestnut where it weaves the cocoon in which to diapause. It pupates at the end of the following spring or in summer. In contrast to *Laspeyresia splendana,* which usually enters and feeds on one chestnut per cup, the larva of *P. fasciana* enters and feeds on all the seeds of a cup. The infested cups drop in early July and August. Therefore, damage passes unnoticed, even if considerable. I.D. Ioannidis (personal communication) established that in the area of the mountains Pelion and Kissavos of eastern central Greece, damage to chestnuts by this species of moth is more serious than that caused by the other two related species *Laspeyresia fagiglandana* and *L. splendana.* In western Crete Kalaitzaki et al. (2005) observed 30-40% of the cups infested by *P. fasciana* from June to early August in the five localities they sampled. Yet, they considered that loss of unripe fruits is of no economic importance, because the infested cups that fell off in July and August, acted as a fruit thinning, resulting in larger size of the remaining fruits. Information on the life history and control of this moth in Spain is given by Mansilla and Salinero (1993).

Control. Same as in other Lepidoptera that infest and injure chestnuts, control of *P. fasciana* with insecticides is difficult. In southern Switzerland, when control is possible and necessary, two sprays with insecticides are recommended in June and July. These sprays are applied on the basis of captured adults in pheromone traps, and are 15-20 days apart. Proper insecticides are those used against the codling moth of apples and other Tortricidae.

***Ectomyelois ceratoniae* (Zeller)** *(Myelois ceratoniae, Spectrobates ceratoniae)* **(Lepidoptera, Pyralidae)**, comm. **carob worm, carob moth**

Adult. It is 8-10 mm long and has a wing span of 20-28 mm. The body is on the dorsal part dark grey and on the ventral one silvery. The forewings are silver-grey and have two light-colored cross stripes with dark margins. The light-colored stripe towards the base of the wing is toothed and a little oblique, while the other one (towards the wing apex) is usually saw-like (Fig. 376). The hindwings are light grey, with the veins and the anal angle darker (Isaakides 1936a,

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Avidov and Harpaz 1969).

Egg. Oval, 0.7 x 0.5 mm, at first white and later red-brown.

Larva. It is pink or light pink (Fig. 377), with brown head and prothoracic shield. On the dorsal surface it has small brown hair-bearing tubercles. Fully grown it is 18 mm long.

Pupa. Brown, approximately 10 x 3 mm, in a light grey cocoon.

Host trees. This species is polyphagous. It infests carobs, citrus fruits, quinces, dry fruits, almonds, pistachios and other nuts, in both the orchard and the warehouse.

Life history and damage. Usually it completes 4, and exceptionally 5 generations per year. It overwinters as a larva inside the infested fruits. The larva continues its growth and pupates in spring. In Israel, the larvae of the first spring generation develop usually in the pods of *Acacia farnesiana* Willd., in soft-shell almonds that are infected by the fungus *Colletotrichum gloeosporioides* Penz., and less often in young carob pods (Avidov and Harpaz 1969, Gothilf 1984). The generations that follow develop mainly in carobs, in almonds the mesocarp of which has started to dehisce, and in citrus fruits, especially grapefruits. The young larva cannot enter in young or ripe carob pods, unless they have cracks or wounds from various causes, such as by fungi or other insects such as *Asphondylia* spp.

Figs. 376-377. *Ectomyelois ceratoniae.* 376.Adult. 377.Larva and its feces in an infested walnut. (photo B.I.K.).

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The eggs are laid mainly on such wounded or infested carobs, especially in their cracks. The larva enters the carobs where it eats the flesh of the pod, without eroding the seeds. Erosion continues in the warehouse, where injury may spread to ground carobs, carob meal, and other stored fruits or nuts. In almonds, especially soft-shell ones, infestation starts in the orchard, before harvest, when the mesocarp dehisces. Injury continues after harvest in fruits remaining on the trees post-harvest. The larva eats the mesocarp, but can also enter the fruits and eat the seed. In Greece, damage to almonds is not serious. In Iran, this moth is a pest of pomegranate and pistachio (Mehrnejad 1995). In that country pistachios are infested in the orchard when the hull (endocarp) starts to dehisce, usually from late July until harvest. The injury concerns the seed and continues in pistachios at storage. In citrus, and especially grapefruits the young larva enters at a point near the base covered by the calyx, and bores a gallery towards the center of the fruit. Sometimes it enters the fruit on the side, at a point of contact of two fruits. Often gum comes out of the hole where a larva entered a grapefruit. This gum sometimes prevents the larva from going further in, or even drowns the larva. Infested grapefruits ripen and become yellow earlier than uninfested ones and finally drop early. Grapefruits infested by citrus mealy bugs seem to attract the adult moths because of the honeydew they excrete. This results in more infestation by *E. ceratoniae* (Avidov and Harpaz 1969). In certain other countries *E. ceratoniae* is becoming a serious enemy of navel oranges, in which the larva enters mainly at the navel, or settles mainly in the navel, affecting the appearance and commercial value of the orange. However, this insect is mainly a pest of ripe and stored carobs and other dry fruits and nuts. Mineo (1967) reported an unusual case where in the area of Palermo, Sicily, larvae of this moth developed to full growth in the laboratory, feeding on the mesocarp of olives of two cultivars that were field-collected during the period July-September.

In walnuts imported from California, a related species of moth was found in Italy, *Paramyelois (Amyelois) transitella* (Walker). It belongs to the same insect family, and resembles *E. ceratoniae* in appearance and habits. The possibility of its coming to Greece in imported walnuts or other fruits from Italy or California cannot be excluded.

Control. For control measures in warehouses, same as against

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other stored product insects, in Greek, see Tzanakakis (1980), and Stamopoulos (1995). For carob and almond trees it is recommended not to leave fruits on the tree or the ground after harvest. For citrus trees, Avidov and Harpaz (1969) recommend sprays with stomach insecticides the last summer months.

Hyphantria cunea **(Drury)** *(H. textor)* **(Lepidoptera, Arctiidae)**, comm. **fall webworm**

Adult. It has a wing span usually of 30-40 mm. Above it is totally white, with long white hairs on the body, and may have or not a few small black dots on the upper and lower wing surfaces (Fig. 378). The antennae are black and white and the abdomen often yellow, with black dots at the tip and the sides. According to Keen (1952), orange spots may also exist on the body and the legs.

Egg. Almost spherical, white, golden yellow, or greenish, in large groups (masses or plaques), usually on the lower leaf surface (Michelbacher and Ortega 1958, from Essig 1926). All or most eggs of an egg mass, and especially those of the perimeter may be covered with sparse or dense white hairs or scales from the maternal body.

Larva. The grown one (last instar) is approximately 25 mm long (according to some authors 30-40 mm), and of a general color ocher yellow, ocher brown-yellow, greenish, or towards grey, and is covered by long whitish hairs, that are located on black or orange hair-bearing tubercles. Usually it has a yellow line along the sides and a dark median one along the dorsum. (Fig. 379).

Figs. 378-379. *Hyphantria cunea.* 378.Adult. 379.Larvae (Zangheri et al. 1992).

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Pupa. Light brown, in a brown cocoon.

Host plants. This insect is popyphagous. It attacks the foliage of many (more than 120) broad-leaved forest, ornamental, and fruit trees and shrubs. It is reported as a pest of walnut, mulberry, pome fruit and stone fruit trees, other fruit trees, and grapevine.

Life history and damage. In California and other regions of North America it originates from, it completes one generation per year (Michelbacher and Ortega 1958). On the contrary, in Italy and other European countries it completes two generations per year, and in certain areas of the former Yougoslavia and in Hungary, a partial third generation is observed (Zangheri et al. 1992). It overwinters as a pupa in a cocoon, usually under dry bark or in other protected sites of the tree, or on the ground under dead leaves, or in the soil at a small depth. It becomes adult in spring. The adults place their 500-1000 eggs mainly on the underside of leaves of the apical part of shoots of the season, in masses of a few hundred. The larvae are gregarious and feed on leaves. Those hatching from the eggs of a mass or of neighboring masses, live together as a group in a nest-shelter made of silk threads. The nest is formed around a shoot, the leaves of which the larvae devour. The young larvae eat the upper side of the leaf. The older and larger larvae devour almost entire leaves, leaving only the midvein and a few secondary veins. As they grow, they expand their nest, which may ultimately cover a whole shoot of the year, or more than one neighboring shoots and become as large as 50 cm or more (Kailidis 1977). The larvae live together, as a group, until their last molt. Subsequently, during their last stadium, some of them (according to some authors all of them) abandon the nest and live singly. When they complete growth they gather and spin their coccons, often many together, one next to the other, at a proper protected site, and pupate (Michelbacher and Ortega 1958). In central Italy, the adults of the generation that has overwintered (2nd) are seen mainly in May, the eggs of the first generation from early May to early June, the larvae in June and early July, the pupae in July, and the adults in mid- to late July. The eggs of the second generation are seen in mid-July to early August, the larvae in late July to late September and the pupae (which overwinter) from early September to mid-May of the following year (Montermini and Oliva 1984).

The degree and frequency of damage varies with the area and is more serious during the second generation of the insect. Certain

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European authors consider *H. cunea* dangerous to broad-leaf trees and shrubs (Stanek 1969, Kailidis 1977).

Control. In regions new to this insect, i.e. where it has spread recently, the introduction from North America or other regions, and colonization, of effective natural enemies of it should be done. In small acreages, the removal and burning, or destruction in some other way, of the nests and the larvae they contain is recommended by certain authors, especially for fruit and ornamental trees. In large areas, when the insect's population density is high and there is danger of substantial defoliation of the trees, spraying or dusting with a contact or stomach insecticide is recommended. The best time is immediately after the hatching of larvae of the first generation.

Dryocosmus kuriphilus **Yasumatsu, (Hymenoptera, Cynipidae),** comm. **oriental chestnut gall wasp, chalcide du chataigner**

For morphology, life history, symptoms on chestnut and control, see Bosio and Vettorazzo (2005).

Host trees. Various species of chestnut, such as *Castanea sativa* (European chestnut), *C. crenata* (Japanese chestnut), *C. mollissima* (Chinese chestnut), and *C. dentata* (American chestnut). It is one of the most widespread pests of chestnut trees in Japan (Kato and Hijii 1997) and in recent years was recorded in northern Italy (Bosio and Vettorazzo 2005).

Life history and damage. According to Kato and Hijii (1997) and Bosio and Vettorazzo (2005), it is univoltine and parthenogenetic. It overwinters as young larva inside the buds of chestnut trees. The larvae grow slowly in autumn and winter. At bud burst in spring they develop rapidly. Pupation occurs inside the galls. The adults emerge from late May to late July. They lay inside the buds of chestnut trees from summer to autumn. Laying induces the formation of galls on new shoots where the larvae develop. The injury to vegetative buds disrupts the growth of twigs, reduces the vigor of trees and reduces fruiting. Heavy infestation may even cause decline and death of trees.

Control. Wherever possible, pruning and insecticides of long residual action are recommended.

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Insects of grapevine

Orthoptera

Decticus albifrons (F.), Tettigoniidae
Ephippigeria ephippiger Fieber, Tettigoniidae
Calliptamus italicus L., Acrididae

Isoptera (termites)

- *Kalotermes flavicollis* (F.), Kalotermitidae
- *Reticulitermes lucifugus* (Rossi), Rhinotermitidae
- *Reticulitermes santonensis* (Feytaud), Rhinotermitidae
- *Reticulitermes urbis* Bagneres and Clement, Rhinotermitidae

Homoptera

- *Hysteropterum grylloides* (F.), Issidae
- *Empoasca decedens* Paoli, Jassidae

  Empoasca flavescens F., Jassidae
- *Empoasca vitis* (Göthe), Jassidae

  Erythroneura eburnea Fieber, Jassidae
  Jacobiasca libyca (Bergevin and Zanon), Jassidae
  Scaphoideus titanus Ball, Jassidae
  Zygina rhamni Ferrari, Jassidae
- *Parabemisia myricae* (Kuwana), Aleyrodidae
- *Metcalfa pruinosa* (Say), Flatidae

Aphids

- *Aphis illinoisensis* Shimer, Aphididae
- *Viteus vitifoliae* (Fitch), Phylloxeridae

Coccoidea (scale insects)

- *Aspidiotus nerii* (Bouché), Diaspididae
- *Quadraspidiotus perniciosus* (Comstock), Diaspididae
- *Pseudaulacaspis pentagona* (Targioni-Tozzeti), Diaspididae

  Targionia vitis (Signoret), Diaspididae
- *Ceroplastes rusci* L., Coccidae
- *Coccus hesperidum* L., Coccidae
- *Eulecanium corni* Bouché, Coccidae
- *Eulecanium persicae* F., Coccidae
- *Pulvinaria vitis* L., Coccidae

  Heliococcus bohemicus Sulz., Pseudococcidae
- *Planococcus citri* (Risso), Pseudococcidae
- *Planococcus ficus* (Signoret), Pseudococcidae

  Pseudococcus longispinus (Targioni-Tozzeti), Pseudococcidae
  Pseudococcus obscurus Essig, Pseudococcidae
  Pseudococcus viburni (Signoret), Pseudococcidae
  Pseudococcus vitis (Niedielski), Pseudococcidae

Hemiptera

Graphostethus servus F., Lygaeidae

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Oxycarenus hyalinipennis (Costa), Lygaeidae

Thysanoptera (thrips)

- ■ *Drepanothrips reuteri* Uzel, Thripidae
- *Frankliniella cestrum* Moultïn, Thripidae
- ■ *Frankliniella occidentalis* (Pergande),Thripidae
- *Thrips tabaci* Lindeman, Thripidae

Coleoptera (beetles)

- ■ *Amphimallus solstitialis* (L.), Scarabaeidae
- ■ *Anomala ausonia* Erichson, Scarabaeidae
- ■ *Anomala dubia* Scopoli, Scarabaeidae
- *Anomala junii* (Duftschmidt), Scarabaeidae
- ■ *Anomala oblonga* F., Scarabaeidae
- ■ *Anomala vitis* F., Scarabaeidae
- *Anoxia meridionalis* Reitter, Scarabaeidae
- *Anoxia orientalis* Kryn., Scarabaeidae
- *Anoxia villosa* F., Scarabaeidae
- ■ *Lethrus apterus* Laxmann, Scarabaeidae
- *Oxythyrea funesta* Poda, Scarabaeidae
- *Polyphylla fullo* (L.), Scarabaeidae
- *Apate monachus* F. Bostrychidae
- *Schistoceros bimaculatus* (Olivier), Bostrychidae
- *Sinoxylon perforans* Schr., Bostrychidae
- ■ *Sinoxylon sexdentatum* Olivier, Bostrychidae
- *Opatrum sabulosum* L., Tenebrionidae
- *Vesperus* spp., Cerambycidae
- *Bromius (Adoxus) obscurus* L., Chrysomelidae
- ■ *Haltica lythri* ssp. *ampelophaga* Guerin, Chrysomelidae
- *Pachybrachys limbatus* Menetries, Chrysomelidae
- ■ *Byctiscus betulae* (L.), Attelabidae
- *Cneorrhinus plagiatum* Schaller, Curculionidae
- *Otiorrhynchus bisphaericus* Reiche, Curculionidae
- ■ *Otiorrhynchus excellens* Kirsch, Curculionidae
- *Otiorrhynchus graecus* Stierlin, Curculionidae
- *Otiorrhynchus lavandus* Germar, Curculionidae
- *Otiorrhynchus longirostris* Stierlin, Curculionidae
- *Otiorrhynchus lugens* Germar, Curculionidae
- *Otiorrhynchus ovalipennis* Boheman, Curculionidae
- *Otiorrhynchus rugosostriatus* Goeze, Curculionidae
- *Otiorrhynchus schläflini* Stierlin, Curculionidae
- *Otiorrhynchus scitus* Gyllenhall, Curculionidae
- *Otiorrhynchus subfillum* Reitter, Curculionidae
- ■ *Otiorrhynchus sulcatus* F., Curculionidae
- *Peritelus sphaeroides* Germar, Curculionidae
- *Psalidium aurigenum* Desbr., Curculionidae

Diptera

- *Contarinia viticola* Rubs., Cecidomyiidae

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Janetiella oenophila (Haimhoffen), Cecidomyiidae
Drosophila melanogaster Meigen, Drosophilidae

Lepidoptera

- *Holocasista rivillei* Stainton, Heliozelidae
  Paropta paradoxus (Herrisch-Schaefer), Cossidae
- *Lobesia botrana* (Denis and Schiffermueller), Tortricidae
- *Sparganothis pilleriana* Schiffermueller, Tortricidae
- *Eupoecilia ambiguella* (Hübner), Cochylidae
  Cryptoblabes gnidiella Millière, Pyralidae
- *Theresimina ampelophaga* (Bayle Barelle), Zygaenidae
  Deilephila elpenor L., Sphingidae
  Deilephila lineata F., Sphingidae
  Deilephila livornica (Esper), Sphingidae
- *Theretra alecto* (Boisduval), Sphingidae
  Arctia caja (L.), Arctiidae
- *Hyphantria cunea* (Drury), Arctiidae
  Euxoa crassa Hübner, Noctuidae
  Noctua comes Hübner, Noctuidae
  Noctua fimbriata (Schreber), Noctuidae
  Noctua pronuba L., Noctuidae
  Scotia segetum Schiffermueller, Noctuidae

Hymenoptera

Wasps

- *Vespa orientalis* F., Vespidae
- *Vespula germanica* (F.), Vespidae

Termites (Isoptera)

In the adults the three parts of the thorax do not differ much in shape and size, and the abdomen is united with the thorax in all its width, without a stem. They have cerci, and their antennae are not elbowed. In the alate forms the forewings are approximately equal to and similar with the hind ones. The apterous forms are whitish or yellowish and do not circulate on the surface of soil, timber, plants, and generally of materials they infest. Therefore, it is easy to distinguish termites (Fig. 380) from ants. Termites are also social insects with different casts or morphs of individuals within each community. Every community lives inside a nest which its members construct in the soil or inside wood. Termites eat wood, wood products, and cuticle and feces of members of their community. They destroy wood of every kind, as well as other materials made of cellulose.

At the beginning of the twentieth century only two species of termite were known to occur in Europe: *Kalotermes flavicollis* of the

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Fig. 380. *Reticulitermes lucifugus* workers (A.U.T., i.e. Aristotelian Univ. Thessaloniki).

Kalotermitidae, and *Reticulitermes lucifugus* of the Rhinotermitidae. Only these two species have been reported in Greece ever since. However, in the last few decades two more species of *Reticulitermes* have been added to the European fauna: *R. urbis* and *R. santonensis* Feytaud, the latter being frequent in France, and considered as synonymous to the North American *R. flavipes* (Kollar) (Vieau 2001). In the last 30-40 years, in northern Italy, a massive infestation by *R. urbis* has been recorded in the town of Bagnacavallo (Ferrari et al. 2011).

K. flavicollis belongs to the “dry wood” termites. It does not need much moisture. Its colonies usually comprise a few hundreds of individuals. It lives usually above soil level, inside poles, trunks and branches of trees and shrubs, cut timber, wooden houses, wood inside houses, and wooden constructions. It can establish itself inside the trunk or canes of grapevines, especially when an above ground part of the plant is dead, or infected by polyporiasis, thus enhancing the death of the rest of the vine by eroding the heartwood. In recent years *K. flavicollis* caused concern in Greece, because of accidents due to the falling of infested trees along streets (Buchelos et al. 2013).

R. lucifugus and the other species of the same genus belong to the “subterranean” or “damp wood” termites. They make their nests in the soil and need a humid environment to function. From their nests, through galleries they construct, members of the colony reach and attack neighboring wood. Their colonies have each thousands of individuals, therefore, the damage they cause is usually more serious than that caused by dry wood termites. It is possible that colonies are established in wooden poles of a vineyard and subsequently,

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through the soil, infest underground exposed wood of neighboring healthy vines. Except heartwood, *R. lucifugus* can consume even the pith of grapevine canes, thus affecting slightly the vigor of the plant. The life history and cast determination of colonies of the genus *Reticulitermes* are complex, and there is marked inter- and intraspecific plasticity (Laine and Wright 2003). Vargo and Husseneder (2009) using population genetic markers, primarily microsatellites, have furthered our understanding of the life history, population biology, community ecology, and invasion biology of subterranean termites of *Reticulitermes* and *Coptotermes,* two economically important genera.

Wounds which expose wood to infestation by termites are caused by agricultural machinery, prunning cuts, pest insects or plant pathogens that kill the bark or the sapwood. Injury by termites usually is not detected until a branch or the whole plant breaks after pressure, or because of strong wind. Old and neglected vineyards are infested more frequently. Buchelos (2010a) gave a list of 24 species of trees and shrubs which he considers susceptible to infestation by termites in Greece and Cyprus. Among them are olive, carob, grapevine, almond, citrus and walnut. He further (2010b) added apricot, fig and palms, in addition to a number of other species of trees.

Control. It is recommended that infested wooden poles and pegs be removed and burned. Also, dead parts of the vines should be removed. Termite nests in the soil should be searched for and dusted or sprayed with an insecticide of long residual action. In localities where the presence of termites is frequent, it is advisable to also impregnate wooden poles and pegs with a fungicide and an insecticide effective against termites, and avoid wounding the vines, especially at the base of the trunk.

Jassidae (Homoptera), commonly known as **leafhoppers**

In the Balkans and southern Europe in general, the grapevines are infested by species of the genus *Empoasca* and of other genera of the family Jassidae (Cicadellidae). The adults have a length of a few mm and look like small cicadas. They pierce and suck the sap of leaves, shoots and other organs of their host plants. Certain species are vectors of plant diseases. Among the species which infest the grapevine frequently, are those included in the above list. Usually they do not cause serious damage, because their populations are kept at bearable densities due to the action of effective natural enemies. However,

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when the action of their effective natural enemies is limited because of the excessive use of insecticides, or the populations of leafhoppers are favored by other host plants (weeds) in or near the vineyard, these Homoptera may locally become important enemies of the grapevine. Such examples come from certain parts of the island of Crete, where *Empoasca vitis* developed to a regular enemy of the cultivars Sultanina and Rozaki (Roditakis 1989), and *Empoasca decedens* from a secondary pest, tends to become a major pest of the vine, in localities where the number of insecticide applications is excessive (Heraklion Crete Region. Centr. Plant Prot. & Qual. Control Annu. Rpt. 1997). The identity of species of Jassidae which infest the grapevine and their population densities on various grape cultivars need further looking into.

Aphis illinoisensis **Shimer (Homoptera, Aphididae)**, comm. **grapevine aphid**

Until recently, this aphid was recorded only in the American continent and islands of the Caribbean. In 2002 it was recorded in southern Turkey, and in 2005 in all major viticultural areas of the island of Crete (Tsitsipis et al. 2005). On that island, a decline of the aphid's population after early August was noticed in most areas. In 2008 it was recorded in several localities of central and northern continental Greece (Margaritopoulos et al. 2009, and references therein). An analysis of a large part of the COI gene of mitochondrial DNA in aphids from Greece and the USA suggests that a parthenogenetic line of American origin has invaded Greece.

Host plants. In the USA it is considered a holocyclic species with *Viburnum prunifolium* as the primary host and the grapevine as the secondary one.

Life history and damage. In North America, the winter eggs are laid on the primary host. After hatching of the first larvae in spring, 2-3 generations are completed on the primary host. Subsequently, winged migrants fly to grapevines (cultivated and wild) where parthenogenetic generations follow. The apical parts of young grapevine shoots, the young leaves and the helices are infested first. Later the aphids spread also to lower leaves and the underside of leaves. In some cases they may also feed on the berries (Tsitsipis et al. 2005 and references therein). The injury is more

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serious if fruit clusters are also infested (Peairs 1948). The aphid excretes abundant honeydew, which rersults in attendance by ants. In certain vineyards of central Greece dense populations developed, and insecticidal applications were required (Margaritopoulos et al. 2009). Thermal requirements and certain demographic parameters have been determined on five Greek cultivars by Moraiti et al. (2011).

Viteus vitifoliae (Fitch) (Homoptera, Phylloxeridae)
(_Phylloxera vastatrix, P. vitifoliae, P. pervastatrix, Dactylosphaera vitifoliae, Dactulosphaira vitifoliae, Peritymbia vitifolii),_ comm.
grape phylloxera

It is a polymorphic aphid, as are other members of the same family. On its main hosts, which are the American species of *Vitis,* 4 morphs (forms, categories) of individuals occur. On the European vine (*Vitis vinifera)* only the root-living (rhizobious) morph occurs and rarely the gall-living one (phyllobious or cecidobious). This is the case whether the European grapevine is on a *vinifera* rootstrock, on an American, or on a hybrid one.

Adult rhizobious. It is wingless, 0.8-1.2 mm long, oval or pear-shaped, wider in the thorax, with small hair-bearing (setiferous) tubercles, and a green-yellow or yellow color during the plant's vegetative period, but brown during winter (Fig. 383, 1d).

Host plants. Species of *Vitis.* The American species are its main hosts, while the European grapevine its secondary one.

Geograpic distribution. From North America, which is its region of origin, the grape phylloxera has been carried to and spread in Europe and other parts of the world. It was first recorded in England and France in 1863, then in Portugal 1865, Germany 1875, Spain 1876, Italy, Hungary and Australia 1879, Austria, Serbia and Rumania 1880, Switzerland and Algeria 1883, Turkey and Russia 1885 (Grandi 1930). On the Greek islands of the eastern Aegean it was recorded from 1892 to 1908, and in the area of Thessaloniki in 1898 (Rumbos 1987). As in other countries, the insect continues to spread in Greece. Until 1974 it had spread to most of continental Greece, except a large part of Epirus and southern Peloponnese. It already exists in a large part of Crete and of other islands. Thus, the European Union and the Greek Ministry of Agriculture consider the whole of Greece infested, and have withdrawn the measures which

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Figs. 381-382. *Viteus vitifoliae.* 381.Galls in leaves of American vine (A.U.T.). 382.Cecidobious individuals and eggs inside a leaf gall which was opened (photo U. Remund).

aimed at delaying the spread of the insect from infested to "phylloxera free" areas of the country.

Life history and damage. The way this insect develops on the European vine (*Vitis vinifera*) differs from that on the American species of *Vitis.* On the Eupopean vine, whether on *vinifera* rootstock or grafted on American or hybrid rootstock, only one morph occurs as a rule, the root morph or form (rhizobious, *radicicola*). Phyllobious (cecidobious, gall-living, *gallicolae*) individuals (see below) are formed

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rarely. In Italy they were observed on vigorous canes (Granett et al. 2001). The root form overwinters in the soil, usually as larva (Fig. 383, 1b,c). When temperature or other conditions allow the insect's activity, adults and larvae pierce and suck the rootlets and roots of the vine, develop, and complete more than 5 generations per year, and at times as many as 12-15. The feeding of the insect at the ends of thin side roots (rootlets) causes the formation of common krebsgalls. A krebsgall, according to Mani (1964) is a nodular swelling (nodosity) as a result of cell proliferation in the root cortex. The cells at the immediate site of feeding are small, the swelling thus assuming a curious reniform shape. As Granett et al. (2001) point out, the nodosities are formed near root tips. They are enlarged, fleshy outgrowths that cause rootlets to bend at the point of feeding. Where the aphid attacks mature roots, tuberosities arise. Tuberosities appear as localized enlargements and are the result of proliferation and expansion of phloem patenchyma cells.

The symptoms of the infestation of the roots as seen above ground, include delayed vegetation, chlorosis, drying of leaves, early leaf fall, and decreased cane growth. The symptoms are more prominent in summer when the vines are heat stressed. Over time the root system collapses and death of the vine occurs. The productivity of the vines may decline as rapidly or slowly as the general health of the vine declines.

In a newly infested vineyard

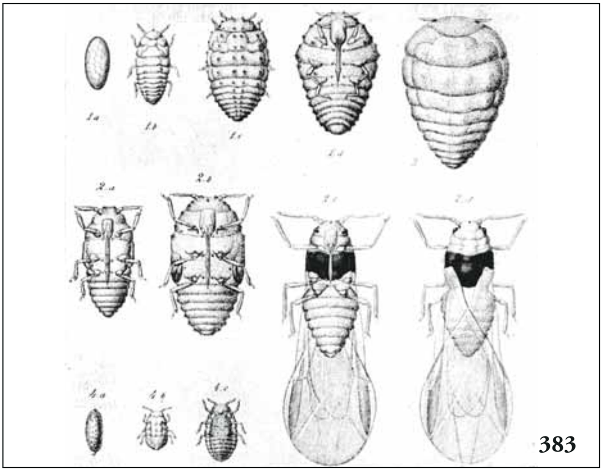

Fig. 383. *Viteus vitifoliae.* Principal forms (morphs) occuring on the American species of grapevine. 1a egg, 1b rhizobious larva in dorsal view, 1c advanced larva in dorsal view, 1d adult rhizobious female in ventral view, 3 adult apterous ghallicolous female. 2a, 2b larvae of the alate form, 2c, 2d adult alate female in ventral and dorsal view. 4a winter egg, 4b male, 4c female (Sta. Firenze, from Cornu).

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the symptoms are initially localized in groups of as few as ten vines. From those focuses vine decline and death expand radially, the number of vines affected increasing at a two- to tenfold rate per year (Granett et al. 2001). The root morph of phylloxera spreads mostly in the following ways and means: 1) With individual insects that move in the soil from root to root. 2) With individuals that move on the soil surface and especially along soil cracks, as often happens in summer. In these two cases the infestation spreads to healthy vines either in spots, or along lines, depending on the distance between adjacent vines and the probability of contact of the roots of one vine with those of neighboring ones. 3) With parts of vines (canes, cuttings) or of other plants from infested soils. 4) With infested soil, ploughs, various infested tools and grape containers. By these means, phylloxera spreads continuously from vineyard to vineyard, and from one area to another.

On the American species of vine (*Vitis riparia, V. rupestris, V. berlandieri, V. labrusca,* and others), which are its primary hosts, the phylloxera has the following 4 morphs or categories of adult individuals: *gallicola* (gall-living, cecidobious, phyllobious), *radicicola* (rhizobious, root-living), *sexupara* (phylogenous or phylogonic), sexuales (male and female) (Fig. 383). Its seasonal development is briefly as follows: It overwinters as a winter egg under dry bark, or in other protected sites of the bark of the trunk, branches or canes of the vine. In spring, after the beginning of new plant growth, foundatory *gallicolae (fundatrices)* hatch from the winter eggs. They settle on the upper surface of tender leaves and each one starts piercing and sucking a given site of the leaf blade. This feeding of a *fundatrix* causes the formation of a gall which takes the form of a pouch of a diameter of 4-5 mm usually. This pouch-gall has an opening on the upper leaf surface and protrudes on the leaf undersurface (Fig. 381). In the gall lives the wingless parthenogenetic oviparous *fundatrix* individual, and lays there approximately 300-500 eggs. The resulting young larvae disperse from the maternal gall and create new galls in which they settle and develop as *gallicolae* (Fig. 382). The *gallicolae* are also viviparous. Sometimes the leaf galls are so numerous as to practically cover the entire leaf (Metcalf and Flint 1939). Galls are less often formed on young shoots and tendrils, but not on mature leaves (Granett et al. 2001). On the European vine the leaf galls are rare and seldom exceed a few to several per leaf. Some larvae of this generation descend to

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the roots where they develop as rhizobious (*radicicolae*). During the vegetative period of the vine more generations of *gallicolae* develop, usually 4-7, each of which gives birth to gall-living and root-living progeny. As autumn approaches, the percentage of individuals that migrate to the roots increases and that of *gallicolae* decreases. In the soil, the first rhizobious generation is followed by other rhizobious ones, up to 10 in southern Italy (Silvestri 1939). In autumn, certain eggs of rhizobious individuals give *sexuparae*, i.e. phylogenous individuals that will give birth to sexual progeny. The *sexuparae* are winged and are distinguished into arrhenotocous (giving male progeny) and thelytocous (giving female progeny) (Fig. 383). These winged *sexuparae* disperse to neighboring vines and lay on the bark a few (1-8) eggs each. From those eggs come the *sexuales,* i.e. apterous male and female individuals which mate, and each female lays a single winter egg. In autumn, the last cecidobious aphids all descend to the roots and give progeny which overwinter there together with the other rhizobious population. The percentage of the rhizobious aphid population that survives until spring depends on the climatic and other conditions of each area.

The damage to the European vines is attributed to soilborne pathogens attacking the feeding site of the insect, and to physiological interaction of the insect with the grapevine (Granett et al. 2001). The root system of American vines is attacked by phylloxera in a manner similar to the European vine, but the American species are able to produce quickly a suberous tissue which isolates the injured part and prevents the spread of rotting of the roots. It also seems that the sap of the roots of American vines is not so suitable as nourishment for the phylloxera as is the sap of the roots of the European vine. Thus, the population of phylloxera is lower on the roots of American vines. Therefore, American vines are resistant to phylloxera. The type of this resistance is tolerance, and perhaps also antibiosis.

Control. Killing the rhizobious phylloxera population in established vineyards without causing serious injury to the vines, is not possible with the means available today. Furthermore, disinfestation of the soil in infested areas, before planting new vineyards, does not guarantee that the insect may not get re-established there. The only effective and practical way of facing phylloxera is the use of resistant plants, i.e. the grafting of European cultivars on resistant rootstocks. Such resistant rootstocks are American species (*Vitis*

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riparia, V. rupestris, V. berlandieri and other), or more often results of crossing American species between them or with cultivars of the European vine. Those hybrids have dominant resistance to phylloxera. In other words, the combination of a European graft on a resistant rootstock creates a plant with a noninfestable foliage and a resistant root system. Depending on the composition of the particular soil and the vine cultivar, a suitable rootstock is selected. Data in Greek language on the resistance to phylloxera of American species of *Vitis* and of their hybrids, as well as on their suitability for given soils, vine cultivars and climatic conditions, are given by Logothetis (1967), Davidis (1975), Vlachos (1986), and Stavrakas (1997). Following the condition and productivity of the vineyard is necessary, in order to detect in time a possible reduction of resistance of a given rootstock to the insect. In California, populations of phylloxera named Biotype B have developed, which injure seriously Rootstock A x R no.1 (a hybrid between *vinifera* and *rupestris).* This rootstock used to be resistant. Also in Germany there are indications of susceptibility to phylloxera of certain American rootstocks (Granett et al. 1996).

Pulvinaria vitis L. (Homoptera, Coccidae)

Adult. In dorsal view the female is oval, almost pear-shaped, with the posterior part wider than the anterior, and with a few transverse folds. According to Balachowsky and Mesnil (1935), its dimensions when at oviposition age are 4-5 x 3-4 mm and its color dark brown, almost black. Kattoulas and Evangelopoulos (1967a) who studied this insect in the Thessaloniki area, reported dimensions much greater 8.4 x 6.3 mm and color yellow-brown to olive-colored, with darker spots. Later, after oviposition, the female becomes dark brown. The body size seems to be affected by the species of host plant and its condition. During the oviposition period the female secretes abundant white cottonlike wax filaments, which form a voluminous ovisac in the back and ventral part of its body, which contains 1500-2000 or more eggs, which are dark brown or reddish or, according to other authors, light orange. This ovisac lies between the female body and the substrate, in a way that the hind part of the body is raised, sometimes at an angle of up to 90° with the substrate (Fig. 384). In a population of Thessaloniki, the mean size of the ovisac was 10.4 x 7.4 mm. The male is alate, light brown, and 1.7 mm long.

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Larva. The first instar is orange-colored, the second instar pale yellow to light brown, and the third instar pale yellow to light green (Kattoulas and Evangelopoulos 1967a).

Host plants. Grapevine, hazelnut, rose, peach, *Alnus* sp., *Crataegus* spp., willow, poplar, and other trees. Despite being polyphagous, in Greece it infests mainly grapevine, and much less frequently other shrubs or trees.

Life history and damage. It completes one generation per year. According to Balachowsky and Mesnil (1935) it overwinters as a second-instar larva, on the bark of canes, branches and trunk (Fig. 385), and in general on twigs and branches of its host plants. Kattoulas and Evangelopoulos (1967a) state that in the area of Thessaloniki this scale insect overwinters as an adult, whereas Paloukis (1983) for the same general area, mentions that it overwinters mostly as a fully grown third-instar larva. The overwintered larva develops to adult in late April to early May. The adult females are seen mainly in May-June and oviposit. First instar larvae are seen in June-July, second instars in August-September, and third instars from mid September to the end of October. Subsequently the larvae overwinter (Paloukis 1983). The first-instar larvae walk and settle mainly on the leaves, most of them on the underside along the central vein and fewer along secondary veins. Larvae and adults, in addition to sucking the sap, produce abundant honeydew which favors the development of sooty

Figs. 384-385. *Pulvinaria vitis.* 384.Adults on a vine cane. 385.Overwintering individuals on the bark of a cane (photo B.I.K.).

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mould fungi and soil the grapes and the whole plant. In grapevines, as well as in fruit trees, the damage this insect causes is sporadic and usually not serious.

Control. In the Thessaloniki area, on the cultivar Rozaki, an insecticidal spray on the 3rd July against young larvae with azinphos-methyl, methidathion, phosalone, phosmet, or a summer oil, was effective (Paloukis 1983). Kattoulas and Evangelopoulos (1967b) also had satisfactory results by spraying the vines with phosalone in late June, when most larvae hatched from the eggs. In case of a winter spray, a 2-3% winter oil alone or with the addition of 0.05% parathion has been recommended (Della Beffa 1961).

In the Balcans and southern Europe in general, the grapevine is infested, usually lightly, by two more species of the same family. They are *Eulecanium persicae* F. and *E. corni* Bouché. They do not form an ovisac. They are polyphagous. They have one generation per year, and a biology similar to that of *P. vitis.* They are controlled with the same measures as *P. vitis.* One more member of the same family has infested the vineyards of northertn Italy the last few decades. It is *Neopulvinaria innumerabilis* (Rathvon), a species much resembling *P. vitis* (Pavan et al. 1996).

***Planococcus (Pseudococcus)* spp. (Homoptera, Pseudococcidae)**, commonly known as **grape mealybugs**

At least two species infest grapevines in Greece: *Planococcus citri* (Risso) and *P. ficus* (Signoret). They resemble in appearance and way of life. Tranfaglia (1981) gives morphological characteristics to distinguish one species from the other. In the area of Heraklion Crete, the species that usually infests the vines is *P. ficus* (Heraklion Crete Region. Ctr. Plant Prot. & Quality Control 1997 Annu. Rpt.). There is need for determining which species of mealybug infest the vines in various parts of Greece, and how harmful each one is. In Italy, *P. ficus* is the most harmful, but *P. citri* also infests vines quite often, while other species such as *Pseudococcus vitis* (Niedielski), *P. longispinus* (Targioni-Tozzeti) and *P. obscurus* Essig are observed there on vines but much more rarely.

P. citri is described in the insects of citrus chapter, because it occurs more often in those trees. For many years it was considered as the only species of mealybug infesting grapevines in Greece. In this country it overwinters not only in cracks of the bark and other

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protected sites of the above-ground part of vines, but also on the roots in the soil at a depth down to 60 cm or more. In spring, when the new vegetation starts, but also in summer, the insect goes to the tender shoots and the axes and pedicels of the grapes. It pierces and sucks sap. Its cottony waxy secretions, honeydew and sooty mold that accompanies them cause also an indirect injury which may be serious. Mansour et al. (2010) cite sources showing that both *P. citri and P. ficus* are also vectors of several viruses causing diseases to grapevines.

Except for the control measures recommended for citrus trees, a winter spray is also recommended in vineyards, using a winter oil, or a summer oil combined with an organophophorous insecticide, or with another suitable insecticide. During the vegetation period it is suggested to arrange the foliage of vines in a way that the grapes are not shaded. This facilitates their coverage with the spray liquid, and especially discourages the mealybugs from settling on the grapes.

In vineyards of central Greece, a dense network of dispensers releasing commercial pheromone formulations for each species of mealybug has been tested. The purpose was the early detection of focuses of mealybug infestation and the timely application of control measures. The method was found promising (Milonas et al. 2011). *P. ficus* infests the grapevine and is controlled in a way similar to that for *P. citri* (see insects of citrus trees).

Drepanothrips reuteri **Uzel (Thysanoptera, Thripidae)**, comm. **grapevine thrips**

Adult. It is 0.6-0.9 mm long, yellowish, with red brown compound eyes and ocelli. The antennae have 6 articless of which the apical three are brownish. The male, on the sides of the 9th abdominal segment has two hairlike apophyses curved inwards, which are crossed at the tip of the abdomen (Silvestri 1939).

Larva. The young one is whitish, with red eyes.

Host plants. Many, among which the European grapevine, American species of *Vitis* and their hybrids, and especially *V. riparia*, hazelnut, willows, oaks, and maple.

Biology and damage. It is reported that in Italy it completes 2 generations per year, while in California 5-6 (Bournier 1957). It overwinters in the adult stage, probably as mated female, in fissures of the vine's dry bark and in other sheltered sites. It becomes active

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in spring, when the new growth starts. It attacks developing buds, tender shoots, leaves, pedicels, inflorescences, and generally every tender plant part. It introduces its eggs in the leaf blades, and covers the oviposition sites with a dark secretion. The larvae pierce or rasp and suck the contents of cells, same as the adults do. After completing their growth, the larvae pupate on the leaves or in the soil (Bournier 1957).

The feeding of this insect causes necroses and scars, and prevents normal development of plant organs. Even short internodes, small leaves and deformed leaves may be the result. The symptoms on leaves resemble those caused by certain fungi (Silvestri 1939). In Italy, as many as 60 larvae per cm^2 of leaf surface were observed (Bournier 1957). In the area of Heraklion Crete the adults become active early (in late March) and the damage to the vines can be considerable (Heraklion Crete Region. Ctr. Plant Prot. & Quality Control 1997). This insect occurs also in continental and insular Greece, but does not infest grapevines there. Therefore, the identification of the species of thrips infesting vines on Crete should be verified.

Control. Usually one timely spray with a suitable insecticide suffices, when the plant is in the first vegetative stages (stages D-E according to the Baggiolini, or 11-13 according to the BBCH scale of grapevine development (Heraklion Crete Region. Ctr. Plant Prot. & Quality Control 1997). For the above internationally adopted phenological stages of grapevine development, see Bloesch and Viret (2008).

Frankliniella occidentalis **(Pergande) (Thysanoptera, Thripidae)**, comm. **California thrips, western flower thrips**

Adult. It is 0.8-1 mm long. The head is mostly yellowish, the thorax mostly brown with parts of it orange, the abdomen brown, the legs mostly yellow with parts of them brown, and the forewings light-colored (Fig. 386). As all thrips, it has an elongate body and very narrow wings, with fine fringes on their margins (Marullo and Tremblay 1993). According to Robb and Parrella (1991) the females are yellow to dark brown and the males always pale yellow.

Egg. Kidney-shaped, approximately 0.2 mm long. Using its saw-like ovipositor, the female inserts its eggs in the parenchyma of leaves or flowers.

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Figs. 386-388. *Frankliniella occidentalis.* 386.Adult on dorsal view (photo E. Hatzivassiliou). 387.Injury to unripe berries of a white grape cultivar (photo B.I.K.). 388,388A.Scars on and deformation of nectarine fruits from earlier feeding by species of Thysanoptera (photo B.I.K.).

Larva. There are two larval instars. Both look somewhat like the adult, but have no wings.

Pupa. There are two stationary stages between the larva and the adult: the prepupa or prepseudopupa, and the pupa or pseudopupa. These stages are in the soil, at a depth of 1.5-2 cm, or in plant debris on the soil surface (Arzone and Vidano 1990).

Host plants. The California thrips is an exteremely polyphagous species. It infests at least 244 species of plants, belonging to 62 plant families. In Greece, its presence was first reported in 1988 on Crete (Roditakis 1991) and in 1992 in northern Greece. It has caused serious damage to grapevines, pepper plants in greenhouses, bean plants, and floricultural plants (P. Katsoyannos 1992b). Under certain conditions it is also attracted to olive during bloom (Daane et al. 2005).

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Life history and damage. According to Robb and Parrella (1991) it is primarily anthophilous. Both larval instars are positively thigmotactic and active feeders. They pierce and suck the sap of tender plant tissues (flowers, young fruits, tender leaves). Prior to molting, second instars become whitish and usually move down the plant to pupate in the soil or plant litter. The adults can feed also on pollen, nectar and eggs of mites such as spider mites. The prepupae and pupae are non-feeding stages. According to P. Katsoyannos (1992b), this insect completes 5-7 generations per year in California. It overwinters as adult in the soil or on low vegetation, or as pupa in the soil. In spring it becomes active and starts ovipositing.

By removing sap and chloroplasts and wounding young, developing plant tissues, this insect, same as some other species of thrips, causes chlorotic spots, scars, escharoses, cracks, or deformation of plant organs. On the grapevine the oviposition slits in flowers, small berries and taxicarpic axes, develop into dark spots of the developed berries (Fig. 387). Such spots are often surrounded by a chlorotic hallow, and lower the commercial value of table grapes. The oviposition slits may also develop to cracks and rots because of secondary infection by microorganisms. In Corinthia, Peloponnese, serious escharosis of grapes of the table cultivar “Soultanina” in 1995 was proven to be caused by this thrips (Tsitsipis et al. 2003). The injury was such that a large proportion of the yield of this table-grape cultivar was accepted only by wineries.

On stone fruits, according to Payne et al. (1991), feeding by this thrips causes russeting on the surface of nectarines and silvering injury to peaches and nectarines. Russeting is caused by oviposition wounds and feeding by small larvae on young embryonic fruit. This injury is magnified in the mature fruit and expressed as russeting, rough fruit texture and tan color that may result in cullage. Silvering is caused by adult and larval feeding on outer-layer pigment-containing cells, and results in bleaching and speckling of the red blush when fruit begins final swell. This benign light-colored blemish is less severe than russeting. Marullo and Tremblay (1993) state that in nectarines the injury, in addition to escharoses and spotting may also cause fruit deformation (Figs. 388, 388A). *F. occidentalis* is a vector of the tomato spotted wilt virus (TSWV) to numerous floricultural and ornamental plants, the tobacco streaked mosaic, and other plant viruses. Furthermore, the erosion of plat tissues this insect causes facilitates the entry of bacteria and fungi. On olive it is

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attracted during the blooming period, but damage is caused when it feeds on young fruits. This occurs when nearby grain fields or weeds are drying, this thrips moving to the olive trees (Daane et al. 2005).

Control. Many organophosphorous and carbamate insecticides, especially systemic ones, have been used against this thrips, e.g. dimethoate, methamidophos, methomyl and oxamyl, but also synthetic pyrethroids such as deltamethrin and cypermethrin, chlorinated hydrocarbons such as endosulfan and lindane, as well as the avermectin abamectin (P. Katsoyannos 1992b). Referring probably to north America, Robb and Parrella (1991) mention that weeds can serve as refuge of the thrips during insecticide applications to grapevines or fruit trees, and that careful coverage of all plant parts is needed. When populations are dense, usually 2 sprays 5 days apart are suggested. They suggest that insecticides be rotated every 4-6 weeks (2-3 generations time of the thrips) to face resistance. In southern Italy, on white table-grape cultivars, when the insect's population is dense, two sprays are recommended, the first at the beginning of bloom, and the second at full bloom. When the insect population density is low, the first spray suffices. In the same region they suggest as intervention density 10-15 insects per blue color trap per week, and 2-3 insects per cyme of the inflorescence (Moleas et al. 1996). This insect's populations become resistant to synthetic insecticides relatively soon. Among the reasons are the short life cycle, and the overlapping generations which increase the exposure of different life stages during a growing season. Bielza (2008) mentions that, in Spain, this thrips was found resistant to a number of chemical classes, and that resistance was due to enhanced detoxification, but also to alteration of the target site as was the case with spinosad. He suggests minimizing and optimizing the use of insecticides (to reduce insecticide pressure), and avoiding the repeated use of the same insecticides or those with cross-resistance. If this approach is not sufficient, he suggests that cultural, physical and biological approaches be incorporated in the control strategy. Pappas et al. (2009) measured the resistance to dimethoate of 25 populations of the thrips collected from vegetable crops and cotton in various areas of Greece and one of Cyprus. Resistance was widespread and its degree varied widely between populations. In Spain too, resistance to a number of classes of synthetic insecticides was found (Bielza 2008). In integrated control programs we should use insecticides as little as possible, and preferably those that allow survival of natural enemies of the thrips.

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Such programs include the release of predatory Hemiptera of the genus *Orius* and phytoseiid mites commercially available, combined with suitable selective insecticides, such as insect growth regulators. On Crete, it was observed that the Hemiptera *Macrolophus caliginosus* and species of the genera *Nabis* and *Orius* reduced the population of *F. occidentalis* (Roditakis 1991). In greenhouses mass trapping with blue sticky traps may also be satisfactory. When planning control, it is worth remembering that the stationary stages of prepupa and pupa are in the soil. Where injury to olive occurs, Daane et al. (2005) recommend to avoid controlling weeds in the olive grove, but to disk areas adjacent to olive groves early, so as to avoid development of populations of the thrips that later migrate to olive.

***Amphimallus solstitialis* L.** (*A. autumnalis, A. lateralis, A. limbatipennis, A. subsulcatus, Rhizotrogus solstitialis*) **(Coleoptera, Scarabaeidae)**

Adult. It is 15-20 mm long. The body is light brown and, except the elytra, is covered by a dense erected light-colored felt. The elytra have sparse hairs along their outer margin and 4 (or 3) protruding ridgelike lines. The tarsi and antennae are darker than the body.

Egg. White, elliptical, 2.5 x 2 mm, becoming distended during incubation.

Larva. It has the characteristic shape of larvae of the family, and a final length of 20 mm.

Distribution. Europe including Greece, Middle East, parts of Asia.

Host plants. It is polyphagous. The larvae feed on and injure the roots of plants of pastures, but also of cultivated plants such as wheat, beets, potatoes, vegetables, grapevines, and of young trees in nurseries.

Life history and damage. In central Europe it is semivoltine, completing a generation every 2 years. It overwinters in the soil as a relatively young larva the first year, and as grown larva the second year. Pupation is reached in spring, and adulthood in late spring. The adults come out of the soil at dusk of relatively warm days. The period of adult emergence from the soil varies with the year, and lasts a few weeks in early summer. The females go to nearby trees, while the males fly in swarms around those trees and finally land near the females to mate. If there are no trees or shrubs in the

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vicinity, both sexes land on low vegetation. The female places each of its approximately 40 eggs in a small cell in the soil. The larvae feed on the roots of host plants.

When young, the larvae cause little damage. By contrast, in the second year, when in the last (3rd) instar, they may cause considerable damage. Such damage has been reported mostly in sandy and other light soils. According to Hurpin (1962) this species in Europe is the most destructive member of the genous *Amphimallus (Amphimallon).* According to him the adults feed little or not at all and cause no substantial damage. Yet, there are reports that even the adults may injure the foliage of various trees and shrubs. Thus, Isaakides (1936a), states that adults have caused injury to the foliage of grapevines in the Velvendo area of northern Greece and elsewhere.

Control. When their use was allowed, long residual chlorinated hydrocarbon insecticides applied to the soil, preferably in autumn, prervented injury for 3-4 years. Against adults various contact insecticides are effective.

In southeastern Europe, some other polyphagous species of the same genus are also harmful, but less so than *A. solstitialis.* They are also semivoltine and overwinter as young larvae the first year and grown ones the second year. Among them are *A. assimilis* Herbst and *A. caucasicus* Gyllenhal. The second one has caused injury to various plants in Bulgaria.

Anomala vitis F. (Coleoptera, Scarabaeidae)

Adult. The body is stout, oval, 15 x 10 mm, often of beautiful dark green metallic color. The color varies, and populations with a dominant metallic blue or purple are not rare (Fig. 389A). Along the hind margin of the pronotum there is a shallow groove. The external

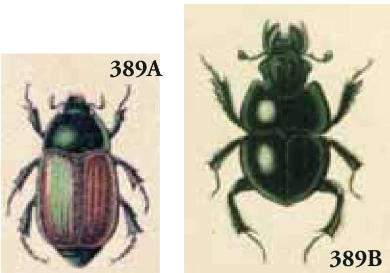

Fig. 389. A.*Anomala vitis* adult. B.*Lethrus apterus.* (Calwer 1893)

tooth of the prothoracic and metathoracic legs is separated in two (i.e. it is bifurcate apically). Macroscopically, *A.*

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vitis resembles other species of the same genus, of which *A. ausonia, A. dubia* and *A. oblonga* have the same life history, and in many Mediterranean countries coexist with *A. vitis.* Therefore, a careful examination of specimens is needed before we can be certain of the identity of this species.

Larva. It has the shape and color characteristic of the other soil-inhabiting larvae of Scarabaeidae.

Host plants. It is polyphagous. The adult attacks the grapevine and various fruit, ornamental, and forest trees and shrubs. The larva feeds on the roots of grapevine, as well as of graminaceous and other plants. According to certain authors, the larvae feed mainly on organic matter under deterioration, and secondarily on live roots.

Life history and damage. In regions with the climate of Greece and Italy, it has one generation per year. As a rule, it overwinters as a larva in the soil. It pupates in spring, and the adults come out of the soil in early to mid-summer. The adult emergence is often massive, and the beetles form big swarms which can cause serrious damage to grapevines, pomaceous and other broad-leaved trees and shrubs. The adults concume leaves, except mid-veins, buds and tender tips of shoots, but can also eat young fruits. They oviposit preferably in sandy and light soil. This is why we meet this species more often in coastal areas (near sea or rivers). The injury the larvae may cause to roots is not noticeable, nor can it be easily estimated. In recent years no considerable damage by this insect has been reported in Greece.

Control. If serious damage by adults is observed, spraying with a proper insecticide is recommended.

Lethrus apterus **Laxman** *(L. cephalotes, L. podolicus, Bolbocerus cephalotes, Clunipes scaraboides, Lucanus apterus)* **(Coleoptera, Scarabaeidae)**

Adult. The body is uniformly black with bluish reflections on the ventral surface. It has a characteristic shape, and dimensions of 17-25 x 11-15 mm. The head is partly encompassed by the curved front margin of the pronotum. The eyes are brown red. The mandibles are big and in the male have a scythe-like side extension on their pleuroventral side, which exceeds the mandible in length (Fig. 389B). The elytra are united and there are no membranous hindwings

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underneath.

Egg. Approximately 6 mm long.

Larva. It has the characteristic shape of the family, with the body curved and final length approx. 30 mm.

Host plants. This insect has been reported as an enemy mainly of grapevine, although it is polyphagous and can also feed on fruit trees, ornamental plants, vegetables, cereals and other cultivated or wild plants such as *Taraxacum officinale.*

Life history and damage. It has one generation per year. It overwinters as an adult in the soil, inside the chamber where it has developed as a larva and pupa. According to data by Hungarian, German and Russian researchers given by Balachowsky and Mesnil (1935) and Hurpin (1962), its biology is approximately the following: It lives in various types of soils, provided they are sufficiently dry and firm. It prefers non cultivated soils, such as near roads, fields under fallow, or in areas permanently non arable. In wheet fields it is found rarely. The overwintered adults start coming out of the soil in spring, usually fron mid April on, and feed for a short period. In some countries they come out earlier. For example, in the Argos Orestiko area of northwestern Greece their first mass emergence was observed in late March to early April. Their activity at that time is limited, and so is the injury they may cause. They soon reenter the soil where every one bores a gallery 15-18 mm in diam. and 50-70 cm in length. In the first 25-30 cm the gallery is at an angle, and in the remaining 50-60 cm approximately vertical to the soil surface (Balachowsky and Mesnil 1935, Isaakides 1936a). The gallery each female bores will later serve as a nest of reproduction and as a shelter. To bore the gallery the adult uses its mandibles, legs and prothorax. By early May, every adult has finished its gallery and is reproductively mature. Mating takes place out of the galleries. After mating, each male settles in the gallery of a female and the two together widen the gallery, and bore short side chambers at various heights. Each chamber will be filled with tender plant material well compacted for the larva to feed on, then will receive an egg, and be covered with a lid of soil. According to Balachowsky and Mesnil (1935) both males and females cut the vine foliage and bring it to the gallery during the day, whereas according to Hurpin (1962), it is only the males that cut the foliage and bring it to the gallery during the night. The egg stage lasts approximately 10 days, the larval 3 weeks and the pupal one 2 weeks. Adults are formed

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in July. Each remains dormant in its larval chamber until the next spring. It then comes out, feeds for a short time on tender foliage and bores its home gallery.

Injury to the plants is therefore caused by the adults. The adults cut off not only grapevine leaves, but also tender shoots and damage can be considerable. They often cut off and injure more foliage than they use in the larval chambers. According to earlier authors cited by Hurpin (1962), damage has been serious in some parts of the insect's distribution. In the first half of the twentieth century, considerable damage was observed in certain grapevine nurseries of the Larissa area (central Greece) (Isaakides 1936a), and in certain vineyards of the Kastoria area (northwestern Greece) (D. Radopoulos, personal communication). Nearby almond nurseries were not attacked, whereas entire young bean plants were taken to the beetles' galleries.

Control. Uncultivated land near the vineyards is where the insect breeds. Therefore, plowing the fields next to vineyards, and plowing or digging the vineyard soils so as to make them unsuitable for the beetles to borrow galleries in are recommended. In Russia the economic importance of this insect has been much reduced since most arable land has been cultivated and new agricultural machinery has been used. One or two timely applications of an organic contact insecticide or even a stomach poison, preferably with a long residual action, will protect the buds and later the foliage.

Sinoxylon sexdentatum Olivier (Coleoptera, Bostrychidae)

Adult. The antennae are flabelliform, their last three articles being considerably larger and wider than the rest. The pronotum and elytra are roughly rugose. The head is conceiled in the prothorax and not seen from above. The pronotum is big, subspherical, and one third of the total body length (Chararas and Balachowsky 1962). The body is subcylindrical, stout, and 5 mm (Calwer 1893), 3.5-4.5 mm (Isaakides 1936a), or 4-6 mm long (Chararas and Balachowsly 1962). The head, pronotum, ventral part of the body and the legs, except the tarsi, are black, while the elytra brown red or chestnut brown, and the antennae and tarsi red (Isaakides 1936a) (Fig. 390). On dorsal


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Fig. 390. *Sinoxylon sexdentatum* adult (Calwer 1893).

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view the elytra are rectangular. On their posterior part which bends downwards, each elytron has one mild dentation and further two spine-like projections at its apex (see Chararas and Balachowsky 1962).

Larva. Fully grown the larvae are 6-7 mm long.

Host plants. It is polyphagous. According to Isaakides (1936a) it lives on all angiosperm plants, with preference to grapevine, olive and fig. According to Chararas and Balachowsky (1962) carob, peach, pear, and mulberry are among the trees also infested. The insect's geographic distribution includes the whole Mediterranean region and western Europe. In all North Africa it is common.

Life history and damage. It bores galleries in the canes of the grapevine and twigs of other trees. According to Isaakides (1936a), it overwinters in the adult stage in its galleries in the canes. The adults come out in April. The female selects a node and bores a cavity at the base of a bud. In that cavity it mates and deposits a few eggs. Subsequently it moves to another node where it bores a similar cavity and deposits a few eggs, and so on, until it terminates its oviposition period. The larvae bore galleries along the interior of the cane. They complete growth in July-August and pupate at the end of their galleries. The adults come out in the same months or in September. According to Della Beffa (1962), probably in Italy, the adult female bores a circular gallery where it oviposits. In trees it prefers twigs 1-5 cm in diameter. The larvae complete growth in August-September. The adults emerge from holes they bore through the bark and reenter the galleries to overwinter. Some late adults do not come out of the galleries but remain there until spring.

Chararas and Balachowsky (1962), give this beetle's life history as studied in the Montpellier area of southern France by F. Picard in 1919. According to Picard, the insect is univoltine in France and North Africa. It infests twigs and other woody parts of various plants. The life history given for France somewhat differs from the one given above. The infestation there is of two types: the one concerns deep feeding galleries made by adults in early spring on woody parts of living plants. On grapevines they are bored on new and living wood. The other type of infestation follows the feeding period. It occurs usually in May or June on sickly trees and exceptionally on healthy ones. It is very frequent on grapevine. It concerns laying galleries which start usually through a bud. The entrance hole is

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approximately circular and directed perpendicularly to the cane axis. It subsequently becomes annular and soon widens. This widened part serves as a mating chamber, and the adults are found there in couples. Subsequently, the mated female bores a gallery along the cane axis and lays a number of eggs. The eggs are ellipsoid, white and with a smooth chorion. The female abandons that gallery, pushing out the yellowish or ochraceous frass. The frass piles up on the soil surface under the vine, and shows the presence of infestation. Subsequently the female bores another similar laying gallery on another cane of the same or of a neighboring vine. The larvae grow slowly, boring longitudinal galleries through the cane. In those galleries the white frass is packed behind the larva and not pushed out of the gallery. Pupation occurs inside the larval gallery. The adults come out in early spring, after boring circular exit holes through the bark. The woody part of the cane is often turned out into powder, and the bark becomes very thin and easily breakable. Infested canes are also distinguished by the sap coming out of exit holes of adult beetles. Such sap soon solidifies (Isaakides 1936a).

According to Isaakides (1936a) this beetle infests preferably weak and sickly plants, in poor sandy soils. Infested canes are easily broken by wind or by people working in the vineyard. The beetle has many natural enemies, especially entomophagous Coleoptera, Parasitic Hymenoptera, and mites of the genus *Pyemotes.* Picard (after Chararas and Balachowsky 1962) also considers this beetle a minor pest of grapevines, the injury usually concerning a few canes per vine, in certain localities only, and never generalized or epidemic. Infestation in France is frequent after frosts and inundations, in vineyards growing under bad conditions or suffering chlorosis, in dry and calcareous soils. Damage of plant species other than grapevine is less frequent. Therefore, *S. sexdentatum* is generally considered of secondary economic importance.

Control. Cultural measures that improve the vigor of the plants reduce the damage caused by this beetle. Della Beffa (1962) recommends removing and burning withered canes and twigs, especially those with frass coming out of galleries.

Haltica lythri **ssp.** ***ampelophaga*** **Guer.** *(H. ampelophaga)* **(Coleoptera, Chrysomelidae, Halticinae)**, comm. **grapevine**

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flea beetle

Adult. The body is oval, 3.5-5 mm long, bright metallic green, and in some populations rather blue. The antennae and the legs are black. Like most species of the subfamily Halticinae, it has the femora of the hind legs much wider and bigger than those of the other legs, and can jump at heights or distances many times the length of its body. It jumps especially when in danger, and can fly well (Balachowsky and Mesnil 1935 and references therein).

Egg. The oval, yellow eggs are laid usually in groups of 2 to 31, but sometimes also singly, on the underside of leaves.

Larva. The young one has a dark, almost black color. Later, yellowish cross stripes appear. The fully grown larva is black, with tubercles on its body, and approximately 8 mm long (Balachowsky and Mesnil 1935).

Host plants. In Mediterranean countries, where it occurs, it infests grapevines and certain other plants, among which willow and species of the genus *Oenothera* (Isaakides 1936a).

Life history and damage. In southern France it completes 2 or 3 generations per year, in Spain (Barcelona area) 3 to 4, and in Algeria 4 to 5, or up to 6 according to Isaakides (1936a). It overwinters as an adult in protected sites, such as in bark crevices, under bushes, under dry leaves on the ground, or between moss in and near the vineyard. The adults come out of the overwintering shelters in spring, and become active shortly after new growth of the vines begins to develop. In southern France and in the Barcelona area this happens in the first half of April. A few days later oviposition starts, mostly on the underside of leaves. Oviposition may continue until late July. Adults and larvae eat the leaves, tender shoots, and unripe berries.

Larvae of the first instar remain in groups on the underside of leaves. When they become second-instar they move to the upper leaf surface. Leaf erosions by larvae and adults are irregular. The larval stage lasts usually 2-4 weeks. Pupation takes place in the soil and adults of the first generation emerge after 1-2 weeks. After feeding and mating, they oviposit on the leaves. In late summer and in autumn, the adults of the last generation, and perhaps some of the penultimate generation, reach protected sites in or near the vineyard, become dormant and overwinter. Early, when the number of tender leaves is relatively small, injury to leaves can be considerable. Erosion of the bark of tender shoots and of green berries is not common. In

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the 19th and first half of the 20th century damage in certain areas of the Peloponnese (southern Greece) was serious. However, in the last seventy years or so, possibly because of the insecticides used against the main pests of grapevine, this insect is not an important enemy of this plant in any Mediterranean country.

Control. This insect has many natural enemies, mainly insects and fungi, but none of them is effective. The adults and larvae are susceptible to almost any organic contact insecticide, and even to stomach poisons.

Byctiscus betulae **(L.) (Coleoptera, Attelabidae)**, comm. **grape cigar maker**

Adult. It has the typical shape of weevils that do not have elbowed antennae. It is 4.5-7 mm long. The color is metallic copper green, or dark blue, and less often dark red with a golden hue, or purple (Balachowsky and Hoffmann 1963). According to Isaakides (1936a), it is 6-9 mm long, rostrum included. The pronotum is rounded and grooved lengthwise. The elytra are at their base as wide as in their posterior part (Fig. 391).

Host plants. Grapevine, pear, hazelnut, chestnut, ash, birch, maple, poplar, willow, and other forest trees.

Life history and damage. It completes one generation per year. It overwinters as adult, usually in the soil, inside the pupation cell. However, in certain areas part of the adult population comes out of the soil in autumn and overwinters in various sheltered sites on or near the trees. The adults become active in spring, usually April-May and feed on leaf parenchyma and bark of tender shoots. In late May to mid-June the female oviposits on the inner surface of a leaf or a group of leaves (depending on the species of host plant) the blade of which it has rolled and glued to form a long cigar-like case (Fig. 393). According to certain authors (Balachowsky and Mesnil 1935, Isaakides 1936a), the female partially cuts the leafstalk so that the leaf withers and can thus be rolled by the female easier. In the grapevine the female rolls 1 or 2 leaves, in pear trees or poplars 4 or 5 together, and in birch more. In every case the female deposits an average of 5-6 eggs, but sometimes only one (Balachowsly and Mesnil 1935). The larvae (Fig. 392) develop by feeding on the inner part of the leaf cylinder. They complete growth in 20-25 days and drop to the soil, where each

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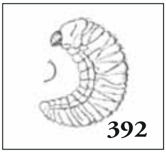
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Figs. 391-393. *Byctiscus betulae.* 391.Adult. 392.Fully grown larva (Sta. Firenze). 393.Removal and curling of part of a grape leaf to form a "cigar". On the right, two "cigars" completed (photo U. Remund).

forms a pupation cell at a small depth. Adults are formed usually in August and remain in the pupation cells or elsewhere (see above) until the following spring.

Control. In older days, this insect caused damage to grapevines in certain localities, and the recommendation was to collect in time and burn the "cigars". Sinse the use of synthetic insecticides in vineyards, *B. betulae* has become rare. In case an infestation occurs, an application of a contact insecticide against the adults will suffice.

Otiorrhynchus (=*Brachyrrhinus*) spp. (Coleoptera, Curculionidae)

Adults. This group of species belongs to the weevils, i.e. to beetles with a dintinct rostrum, and to the family that have elbowed antennae. Their rostrum is relatively short and widens apically (Fig. 394). The elytra are united, and there are no hind (membranous) wings underneeth. Therefore, these weevils cannot fly. Consequently they move and disperse by walking. Most *Otiorrhynchus* have a dull dark brown, rust, or black color (Figs. 394, 395). Most species are parthenogenetic, but in some ones males appear rarely (Hoffmann 1963b). They are nocturnal and polyphagous. Some species have a distinct preference for a certain plant species or for the members of a certain plant family.

Life history and damage. As a rule, they have one generation per

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Figs. 394-395. *Otiorrhynchus sulcatus.* 394.Adult on dorsal view (A.U.T.). 395.Adult on side view, and erosions it made on a grape leaf (photo P. Kunz).

year. Most species overwinter as fully grown larvae, each in a cell in the soil. They pupate and become adults in spring. Some species overwinter as adults in the soil. During the season they are active, the adults hide in the soil or in other shelters at the base of host plants. At night they ascend the foliage and feed on buds, young grafts, tender shoots, leaves, and even inflorescences. Most species erode the leaves by removing semicircular parts of the leaf blade perimeter (Fig. 396). Yet, *Otiorrhynchus sulcatus* F. causes irregular notched erosions to the leaf blade (Hoffmann 1963b) (Fig. 395). The *Otiorrhynchus* weevils oviposit usually in spring, in the soil or on the foliage. In the latter case the eggs drop to the ground. The larvae live in the soil, feed on roots and are polyphagous. They feed on rootlets, roots, undergroung bark of vines and other host plants, trees or herbaceous plants. The observable injury is caused by the adults. In Greece, at least 11 species of this genus have been reported to feed on grapevines (see respective list) and the degree of damage varies with the species of weevil. Two or more species may coexist in the same vineyard. They can also injure pomaceous trees, and other Rosaceae.

Otiorrhynchus sulcatus often attacks grapevines in western and central Europe and occurs also in Greece. In the San Joaquin Valley of California where it occasionally infests olive, it overwinters in the soil and the adults emerge in March (Daane et al. 2005). According to Georgis and Poinar (1984) this weevil in California is a pest not only

Fig. 396. Erosions of olive leaves by the feeding of adults of a species of *Otiorrhynchus* (photo B.I.k.).

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of greenhouse plants, but also of tree nurseries. The adults feed on the leaves, but the larvae do the most damage by feeding on the roots or crown and eventually causing collapse and death of the plants.

According to Isaakides (1936a), in *Otiorrhynchus excellens* Kirsch. and other species of the same genus that infest grapevine, the adults appear in vineyards from late March in the warmer localities, and in April in the cooler ones, and are present until late May. They first feed on buds and young shoots. Later they feed on leaves and bark. When attacked by a dense population, the vines look as if hit by hail. The main injury begins when the buds swell, and continues until the developing shoots reach a length of 4 cm. The injury to buds and shoots affects also the yield of the next year. The populations of these weevils have been much reduced in recent years.

Control. In areas where damage is frequent, it is recommended to spray the vines with a contact synthetic organic insecticide of great or even medium residual action. One compatible with integrated control of vine enemies should be preferred. It should be applied when the buds swell, unless local experience shows that it should be applied a little later. Daane et al. (2005) suggest that insecticides be applied to the trunk and the base of the trunk. In the past, when effective insecticides were not available, the growers smeared a sticky substance around the trunk to prevent the weevils from reaching the foliage.

In spring and especially during the time of bud development, grapevines may be injured in certain localities also by larvae or adults of other leaf-feeding species, belonging to the families Phaneropteridae, Tettigoniidae, Scarabaeidae, Tenebrionidae, Chrysomelidae, Arctiidae, Zygaenidae, Sphingidae and Noctuidae (see list). They are controlled in the same way as the weevils, with contact insecticides. Against larvae of Noctuidae of late instars, which at day hide in the soil near the trunk of vines, it may be necessary to also spread an insecticide-bran bait a little before dark.

Holocacista rivillei **Stainton** (*Antispilla rivillei*) **(Lepidoptera, Heliozelidae)**, comm. **grape leaf miner**

Adult. It has a wing span of 3.5-4 mm. According to Silvestri (1943) and Zangheri et al. (1992) the forewings are narrow and almost black or shiny black, with 4 triangular golden yellow spots, 2 near their

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anterior and 2 near their posterior margin (Fig. 397). The hindwings are greyish.


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Figs. 397-398. *Holocacista rivillei.* 397.Adult. 398.Larval gallery in a grapevine leaf (Zangheri et al. 1992).

Larva. The neonate larva is flat, light yellow, with a brown head. The grown larva is 4 mm long, light yellow, with head, prothorax and last (10th) abdominal segment brown (Zangheri 1992). According to Silvestri (1943), up to the end of the 3rd stadium the larva is approximately 3 mm long. During the last (4th) stadium it is shorter, 2 mm, and has no brown parts.

Pupa. Light brown, 2-3 mm long, in a 3.8 x 2 mm white coccon which is completely covered by the epidermis of a vine leaf (Fig. 398).

Host plant. Grapevine.

Life history and damage. On the Greek island of Euboea, according to Lelakis (1961), it completes 2 generations per year and overwinters as pupa, inside its characteristically covered cocoon, in fissures of dry vine bark, or at a small depth in the soil. According to Silvestri (1943) it becomes adult in June-July and oviposits on the upper surface of vine leaves. The larva enters the mesophyl where it first bores a serpentine gallery. Later, it widens the gallery, which becomes a chamber of various shape (oval, oblong, or irregular) in which it pupates (Fig. 398). In Italy, according to Zangheri et al. (1992), it overwinters as a fully grown larva in a cocoon and completes 3 generations per year. According to their diagram for northern Italy, the adults of the overwintered (third) generation are seen in May. The eggs of the first generation cover the period from mid-May to approximately mid-June, the larvae mid May to early July, the pupae mid-June to mid-July, and the adults the whole of July. The eggs of the second generation are seen from mid-July to early August, the

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larvae from late July to end of August, the pupae mid-August to mid-September and the adults mid-August to mid-September. The eggs of the third generation cover the period from early to late September, and the larvae from late September to early May. The fouth-instar larva cuts off and unites the upper and lower epidermis of the site of its gallery to form a protective case around it, and lets itself drop to the vine bark or the soil.

In Greece, same as in most other countries of the northern Mediterranean coast, the damage varies with the area and the vine cultivar. It is not frequent and seldom serious. On Euboea damage was noticed on vines of the cultivars Eftakilo, Rozaki and Sultanina when grown as trellis (treillage) (Lelakis 1961). Numerous parasitoids usually keep this moth's populations at low levels.

Control. When necessary, control should be directed against the adult moths and the young larvae. Certain organophosphorous insecticides were tried many years ago, but there are no published data on their effectiveness.

Eupoecilia ambiguella **(Hübner)** *(Clysia ambiguella, Cochylis ambiguella)* **(Lepidoptera, Tortricidae)**, comm. **European grape berry moth, cochylis**

Adult. Body length 6-7 and wing span 12-15 mm (Bovey 1966). It can be distinguished easily from the other European grape berry moth, known as the eudemis (see below), because its forewings are yellowish and have in the middle a wide, trapezoid, dark brown or black stripe. This stripe is wider on the costa (Fig. 399). For drawings of adult see also Silvestri (1912c).

Larva. It has a final length of 11-12 mm. The color is usually grey-green or reddish, and the head and prothoracic shield black or brown (Balachowsky and Mesnil 1935) (Fig. 400).

Life history and damage. In central Europe, where it has been studied thoroughly, it completes 2 generations per year. It overwinters as pupa on the vines or in nearby sheltered sites. It lives and infests the grapevine and other plants in a way similar to that of the eudemis (*Lobesia botrana*) (see below), with which it co-exists in many regions of Europe. In the warmer regions of Europe the eudemis occurs exclusively or is the dominant species of grape berry moth. As we

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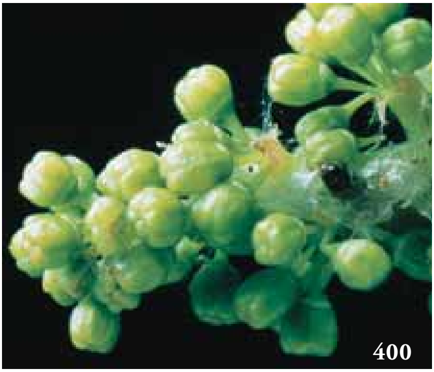

Figs. 399-400. *Eupoecilia ambiguella.* 399.Adult. 400.Eroded grape inflorescence. In the middle of it protrudes the larva's black head (photo U. Remund).

move northward and to higher elevations, the frequency and damage by the cochylis moth increase, until the northern limits of viticulture, where the cochylis is dominant. The cochylis was noticed in the area of Kavala, northern Greece, but in population densities clearly lower than those of eudemis (Stavraki et al. 1987). For the time being cochylis does not constitute an important pest of grapevines in Greece. If necessary, it is controlled in the same way as the eudemis (see below).

Lobesia botrana **(Denis and Schiffermueler)** *(Eudemis botrana, Polychrosis botrana)* **(Lepidoptera, Tortricidae)**, comm. **European grape berry moth, European grapevine moth, eudemis**

Adult. According to Bovey (1966), the average body length is 6 and the wing span 11-13 mm, whereas according to Balachowsky and Mesnil (1935) they are definitely greater. The forewings are grey-yellow with characteristic dark or black patches and spots. The basal part of these wings is brown-green. From the middle of their foremargin starts a dark cross stripe, which narrows backwards and finally bends towards the wing apex (Fig. 401). Silvestri (1912c) described in detail the external morphology of adults and larvae and gave detailed drawings.

Egg. Seen from above it is almost circular, approximately 0.65-0.8 x 0.6 mm. At first it is yellow, and later becomes light grey iridescent.

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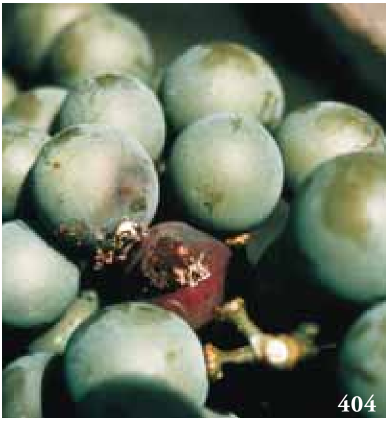

Figs. 401-405. *Lobesia botrana.* 401. Adult (photo U. Remund). 402.Egg on the calyx of a closed grape flower (photo U. Remund). 403.Erosion of an inflorescence by a larva (photo U. Remund). 404.Injury to grape berries by a larva (Zangheri et al. 1992). 405.Larva coming out of an infested berry (Zangheri et al. 1992).

Under magnification its surface looks almost smooth.

Larva. It has a final length of 10-12 mm. The last-instar one (Fig. 405) is yellow-green, brown-green, or dark geen-grey. The head is

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yellow-green approximately 0.9 mm wide, the prothoracic shield brown, and the anal plate light yellow. The larva is active and agile.

Pupa. It is dark brown, 4.7-6.7 mm long in the female and a little shorter in the male. The anal cone ends in a fanlike surface, with 4 dorsal and 4 pleurodorsal fine hairs. The cocoon is white.

Host plants. *Daphne gnidium* of the Thymeleaceae is considered its original host in nature. Of the cultivated plants it infests mainly the European grapevine. However, the larva can feed and develop on certain plants of other families, Bovey (1966) thus considering it a polyphagous insect. In nature, the adults oviposit and the larvae of the first generation develop satisfactorily also on olive inflorescences, when olive trees are near vineyards. In the Kavala area of northern Greece, eggs of this species were found also on young fruits of plum, near a vineyard (M. Savopoulou-Soultani personal communication). In southern Italy, an infestation of a small percentage of fruits was recorded in an actinidia (kiwi) plantation which was near a recently eradicated vineyard (Moleas 1988). However, this insect most probably cannot complete in sequence all its three or four generations in other fruit trees except grapevine.

Life history and damage. In Greece it completes 3 generations per year in most areas, and 4 in some. It overwinters as a pupa, inside a cocoon, under dry bark of the vines and in other natural refuges on or near host-plants, or in the soil at a small depth. The adults of the overwintered generation (usually of the third), appear in April and May. They are active at dusk and have a zigzag flight. If, at that time, the vine inflorescences are developing or have developed but the flowers are still closed, the females oviposit on the closed flowers, and especially on the pedicels and bracts (Fig. 402). If the inflorescences have not yet developed, the eggs are deposited on young leaves or on the bark of young shoots. The first generation is anthophagous (flower-feeding). The larva bores a hole and enters a closed flower, and consumes the stamens and the pistil. Subsequently it infests in the same way neighboring flowers, until it completes its growth. It unites infested flowers and neighboring ones with silk threads (Fig. 403). It pupates in a cocoon in the infested inflorescence, or under dry bark of the vine, or at another shelter, or even in the soil. The adults of this (first) generation oviposit on the small green berries, on their pedicels, or on grape axes.

The larvae of the second generation which are carpophagous (fruit-

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feeding), same as those of the third, enter the green grape berries and destroy one after another, until they complete their development. They often unite with silk threads the berries they attack. Usually they enter at the point of contact of a berry with another one, or with a leaf or shoot. They pupate within berries of which they have consumed the mesocarp of, or under dry bark or other refuges. The adults of this second generation oviposit also on the fruits. The larvae infest the berries which then have attained their final size and start to ripen, or are already ripe (Figs. 404, 405). When they have completed growth they spin their overwintering cocoon at the protected sites already mentioned, pupate, and overwinter in the pupal stage.

The periods of appearance of adults of the generation that overwintered (usually 3rd), and those of the first and second, as concluded from captures in pheromone traps, were, respectively, April-May, June-July and August-September in Heraklion Crete (Roditakis 1987), as well as in Attica and Larissa (central Greece) (Broumas et al. 1994, 1995). In Amynteon Florina (northwestern Greece) the respective periods were mainly April-May, July, and August-September in an “early” year, and June, July-August and September in a “late” year (Kyparissoudas 1990c). In the area of Kavala (coastal northern Greece), in vineyards of the cultivar Rozaki, the periods were April-May, June, and August. In the same area eggs were observed in April-May, June-July and August, while larvae of various stages covered the period from 10th May until at least late August (Sravraki et al. 1987). In the southwestern grape-growing area of Cyprus, pheromone trap captures over a number of years indicate the completion of 3 or 4 generations of the moth, depending on the altitude (Michael and Stavrinides 2013). Silvestri (1912c) described long ago the life history of this moth in Italy.

Damage is usually more serious in cultivars with compact grapes and on trellis. In addition to direct injury because of the destruction of berries and their pollution by the feces of larvae and the silk threads entangling the grape, there is rotting of the grapes caused by fungi or other plant pathogenic microorganisms. Those microorganisms infect the berries that are wounded by larval feeding, and subsequently infect neighboring healthy berries, especially under humid weather. The fungus *Botrytis cinerea* Persoon which causes brown rot, is a frequent consequence of the berry moth attack, especially in autumn on ripe or almost ripe berries. Berries infected by this fungus are better food for berry moth larvae than are healthy berries (Savopoulou-Soultani

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and Tzanakakis 1988). Therefore, the insect is also favored by this undesirable fungus. Other pathogenic microorganisms favored by this insect are the fungus *Botryosphaeria dothidea,* known as Macrophoma, and those causing sour rot of grapes (Rumbos 1987). Berries injured by moth larvae also favor the establishment of other undesirable insects, such as species of *Drosophila.*

Control. It is usually based on synthetic insecticides and less often on microbial ones. The microbial insecticides (formulations of *Bacillus thuringiensis*) are selective. They do not harm entomophagous insects or acarophagous mites, and are not dangerous to man. Yet, their effectiveness against the carpophagous larvae of the moth is not such as for them to be recommended in table cultivars. They are suitable only for wine cultivars. They should be applied shortly before larval hatching and preferably with warm weather (Broumas 1996). Among the insecticides interfering with normal insect growth and development, fenoxycarb is toxic also to eggs of the moth, if applied shortly before oviposition or up to 2 days after oviposition. For this reason it is used in many areas alone or together with a microbial insecticide.

Organophosphorous insecticides are effective against the adult moths. Some of them are effective also against larvae, provided the larvae are at a small depth in the berries. As a rule, these insecticides should be applied between the first and the last hatchings of larvae of each carpophagous generation. The exact timing depends on the properties of each insecticide and some other factors (Angelakis 1996). Certain stable synthetic pyrethroids are also effective against the moth and less dangerous to humans, but reduce much the populations of acarophagous arthropods. The result is dense populations of and injury done to the plant by phytophagous mites. Usually, there is no need to take control measures against the eggs or larvae of the first (anthophagous) generation, except in certain areas like Kavala, where the insect's population may at times be very dense. One spray with *Bacillus thuringiensis (B.t.)* when the population reaches the intervention threshold is recommended (Broumas 1989). Against eggs and larvae of the 2nd, 3rd and possible 4th generations, i.e. against those that injure the fruit, 1-3 sprays are usually applied.

In two-year experiments in Greece, comparing various insecticides on certain wine and table cultivars, a satisfactory protection was achieved when the timing of intervention was based on captures of male moths in pheromone traps (Broumas et al. 1994, 1995, Savopoulou-

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Soultani et al. 1994). In most cases the moth's population density was not high. Milonas et al. (2001) developed temperature summation nonlinear models to predict the time needed for the completion of each generation of the moth in two areas of northern Greece. The day-degrees required for the completion of the first generation were significantly lower than for the 2nd and the 3rd one. Their models predicted with sufficient accuracy the accumulated male moth catch

Fig. 406. Type Delta pheromone trap to capture adult male moths (photo B.I.K.).

in pheromone traps. They conclude that the day-degree models could be useful for a better timing, especially of biorational insecticides that require high precision in their time of application.

In most European countries the number of males caught in traps (Fig. 406) has no close correlation with the degree of injury to the berries, therefore, it is not the main criterion for timing the insecticide applications. Angelakis (1996) comes to the same conclusion. However, the captures of males in traps is a useful index of when should the counting of eggs and hatchings of the 2nd and 3rd (or possible 4th) generation start on the grapes, according to whose number the spraying dates are determined. For the proper timing of insecticidal applications, the insecticides to select and details on the control of the eudemis in Greece, see Angelakis (1996) and Broumas (1996). The state plant protection warning stations follow the adult population density throughout the growing season, as well as the

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periods of oviposision and hatching, and advise the grape growers in time. In central and southern Italy, the intervention density for the 2nd generation was 3-5% of grapes bearing eggs or larvae. For the 3rd generation it was 3-5% for wine and 2-3% for table cultivars (Moleas 1981, Tranfaglia et al. 1981). According to Broumas (1996), if fenoxycarb is used, the spray must be done 3-5 days after the beginning of captures of adults in pheromone traps. If need be, that is if oviposition continues, the spray against the 2nd generation is repeated 10-15 days later. If *B.t.* is used, or a contact insecticide without ovicidal action, the first spray should be done later, 10-12 days after the beginning of increase of male captures, i.e. during the period of larval hatchings. Usually a second spray is needed 2-3 weeks later, depending on the insecticide's residual action and the duration of the oviposition period. If *B.t.* together with fenoxycarb is used shortly before the first hatchings, a single spray usually suffices. In areas, conditions and cultivars where brown rot caused by *Botrytis cinerea* is favored, the limit of tolerable density of grape infestation is smaller, therefore, the intervention threshold is lower. In other words, in certain areas, whether one or two sprays against each carpophagous generation shoud be applied, depends on the probability of injury by the brown rot. According to Egger and Borgo (1981), the simplest and cheapest way to determine the time of intervention for Italy, is to start sampling the grapes (to determine infestation) on the basis of certain phenological stages of the vines, and not on male captures in pheromone traps.

When the insect's population is not followed, the first spray (if needed) is dome when the vine flowers are still closed (a few days before they open), the second one when the berries have the size of a pea, and the third one when the grape has become more compact, the beries change color and ripening starts. This latter stage, is known in Greek as "perkasmos" and in French as "veraison". It is Stage M according to the Baggioloni, or Stage 81 according to the BBCH scale or code of grapevine development (Bloesch and Viret 2008 and references therein).

In the area of Thessaloniki, Ifoulis and Savopoulou-Soultani (2004) compared the efficacy of two formulations of *B.t.,* a wettable powder and a dust, in a vineyard with eleven grapevine cultivars. A single dusting proved better in cultivars with loose, medium or dense berry cluster cultivars, while double sprinkling was more effective in compact-cluster cultivars.

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Disruption of mating by placing a network of dispensers of sex pheromones in the vineyard has given encouraging results at a reasonable cost in various European countries, when the insect's population density was not high. The results of this method have been encouraging also in four areas of Greece (Tsitsipis et al. 1993, 1995, Paloukis et al. 1994, Broumas 1996). In the areas of Elassona and Atalanti the method was tested on wine cultivars for 5 years. Grape production was protected equally well in the mating-disruption vineyards and in those receiving the usual insecticidal sprayings (Tsitsipis et al. 1993). In recent years, inproved dispensers gave a satisfactory release of the pheromone for much of the growing season. In northern and central Greece, placing such dispensers only once in the vineyard, when the adults of the overwintering generation emerged, resulted in a satisfactory reduction of infestation of grapes at harvest as compared to 3 sprays with *B.t.* or with IGRs, or with other insecticides (Zartaloudis et al. 2009). It is considered that mating disruption may be satisfactory if applied for at least 3 to 4 continuous years and in fairly large vineyards (Dvora *et al.* 2005). Ioriatti et al. (2004) conclude that mating disruption is a very promising sustainable tool for effective management of vine moths in Italy. In Israel, where *L. botrana* is a key pest of vineyards, the reluctance of vine growers to adopting the mating disruption method was attributed to the high cost of this method compared to that of using insecticides (Gordon et al. 2005). To reduce the cost of mating disruprion, so as to make it more attractive to vine growers, those researchers compared two different pheromone formulations and two different concentrations of each. The pheromone dispensers were placed in the vineyard at the onset of moths of the 2nd generation. Their results suggest that both formulations were equally effective and the lowest concentration was sufficient to maintain good control of low populations of the moth. When moth population densities were high, control was not improved by a higher pheromone concentration in the dispensers. Therefore, the cost of control can be reduced by reducing the concentration of the least expensive pheromone formulations. However, when moth populations are high, control should be supplemented or replaced by other measures.

Sparganothis pilleriana **Schiffermueller (Lepidoptera,**

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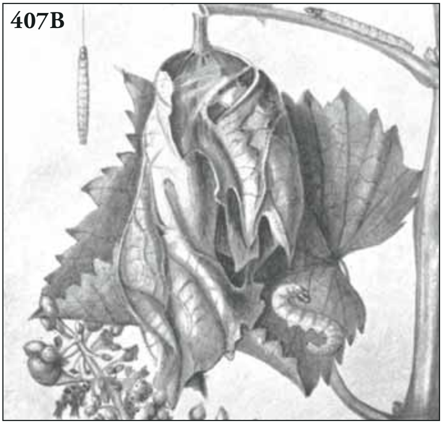
Fig. 407. *Sparganothis pilleriana.* A.Adult. (A.U.T.). B.Entanglement of grape leaves caused by larvae (Sta. Firenze, from Audouin).



Tortricidae), comm. **grape pyralid**

Adult. Body length 10-15 and wing span 20-25 mm. The forewings are yellowish with three darker and arched cross stripes in the male. These stripes are a premedian, a postmedian and a preapical. In the female these stripes are not clear. The hindwings are grey. The thorax is yellow and the abdomen light grey (Silvestri 1943) (Fig. 407A).

Egg. From greenish to grey, in masses of usually 50-60 eggs, on the upper leaf surface.

Larva. Has a final length of 30 mm and a color which varies from grey to greenish or reddish. The head and the prothoracic shield are dark brown (Balachowsky and Mesnil 1935).

Host plants. It is polyphagous, feeding on many species of herbaceous and woody plants, such as *Malva, Rosa, Rubus, Prunus, Juglans, Nerium, Platanus* (Silvestri 1943), and has a strong preference for the grapevine.

Life history and damage. It is univoltine. It overwinters as a first-instar larva under dry bark, bark crevices, or other refuges in the vineyard. In southern France the larvae become active approximately in mid-April, when the vine buds are developing. At first they eat buds and subsequently tender foliage which they cover or unite with abundant silk threads. They unite two or more leaves and thus form a protective nest, same as many other leaf-rolling lepidopterans (Fig. 407B). Later they attack the grapes. They pupate inside the folded leaves. They become adults and oviposit in June-July (Balachowsky and Mesnil 1935). The newly hatched larvae weave cocoons in

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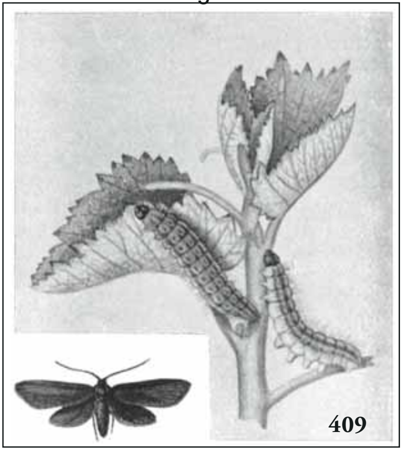
protected sites and enter diapause.

Infestations of vineyards by this insect are rare and not serious. If necessary, one spray with a contact insecticide in spring is sufficient.

Theresimina ampelophaga **(Bayle Barelle)** *(Ino ampelophaga, Proctis ampelophaga, Zygaena ampelophaga)* **(Lepidoptera, Zygaenidae)**

Adult. The body is 10 mm long, and the wing span 20-25 mm. The body color is dark blue or dark green, with metallic reflections. The forewings are dark brown or bluegreen and the hindwings even darker.



Figs. 408-409. *Theresimina ampelophaga.* 408.Adult on a grape leaf (Zangheri et al. 1992). 409.Adult and larvae on a grapevine shoot (Sta. Firenze, from Audouin).

It seems that the wing color varies, as concluded from differences between different authors. The hindwings are much smaller and shorter than the forewings (Figs. 408, 409). For pictures of adult, eggs and larvae see Zangheri et al. (1992).

Egg. According to some authors it is round, 0.6 mm in diam. and almost white, whereas according to others it is oval, 0.75 x 0.5 mm, green and later greenbrown (Balachowsky 1972).

Larva. Short and stout, 15-20 mm long when fully grown. The general color is yellow-grey, with 4 lines of small hairy tubercles along the dorsum. It looks very hairy, especially when young (Fig. 409).

Host plant. The grapevine *Vitis vinifera.*

Distribution. It is reported to follow, more or less, the zone of *Vitis vinifera,* and be limited in the north by the July isotherm of

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19°C. However, damage has in the past been recorded mainly in the Euromediterranean and eastern distribution (Balkans, Cyprus, Middle East, Crimea and Caucasus).

Life history and damage. In Hungary and in central and northern Italy it completes one generation per year, whereas in warmer areas of Italy and in Greece two generations per year are reported (Isaakides 1936a, Silvestri 1943, Logothetis 1967, Zangheri et al. 1992). In Hungary, same as in the rest of central Europe where it completes one generation per year, it overwinters in the late second or the third larval stadium, in a coccon in various protected sites and mainly on the grapevine, such as under dry bark, or in cavities of old branches. The larva becomes active in early spring, when the buds have swollen and start to open. It feeds on the inner part of the buds, keeping the posterior part of its body exposed. Infested buds usually drop. Subsequently, the larva attacks the tender new shoots and later the leaves, causing widespread erosions. Pupation occurs in May, in a cocoon on a woody part of the host plant. Adults emerge in early June and oviposit a few days later. Eggs are laid in groups of 20 to 80, on the underside of leaves. The young larvae remain close to one another and cause small erosions of the leaf, sparing the upper leaf epidermis. After becoming second instar they consume also the upper leaf epidermis, and the leaf looks as if perforated by shot holes. At the end of the 2nd or 3rd stadium, at approximately mid summer, the larva stops feeding and selects a protected site where it will enter diapause and remain there until the end of winter. Thus, larval development is completed the next year (Balachowsky 1972). A similar univoltine seasonal history is reported for the cooler parts of Italy (Zangheri et al. 1992).

No details on seasonal development have been reported from Greece. On a coastal site of Halkidiki (northern Greece), the senior author observed infestation of leaves of a single plant in mid June by many small larvae of 2nd or perhaps 3rd instar. A few days later those larvae abandoned the foliage to spin their diapause cocoons. On the same plant, on May 21 of the following year he observed larvae of an advanced, possibly last, instar on leaves and shoots. A large part of the blade of nearby leaves had been consumed. Those larvae taken to the laboratory continued to feed on grape leaves and, at room temperature, all had pupated by the end of May. Ten days later the adults emerged. They mated and oviposited within their first few

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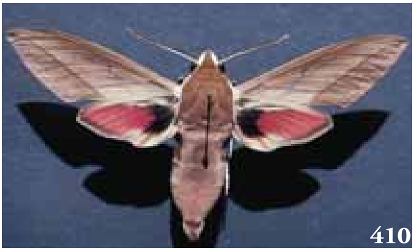
days. Detailed studies are needed before one concludes that in Greece and other countries of southern Europe the insect completes more than one generation per year, as reported by earlier authors.

When the population is dense, *T. ampelophaga* can defoliate the vines, destroy the buds and annihilate the crop. However, such heavy damage has been observed mostly in the 19th century. Today this insect does not occur frequently in Greece and is not reported to cause economic damage in most other countries, except rarely and locally. Possibly the programs to control other grapevine pests have decimated its populations.

Control. In spring, whenever extensive erosions of buds or leaves are observed, an insecticidal spray or dust should be applied. The proper time is when the buds have swollen but not yet developed (Logothetis 1967). This is advisable when in the previous summer dense larval populations were observed on the leaves.

Theretra alecto **(Boisduval)** *(Chaerocampa alecto)* **(Lepidoptera, Sphingidae)**

It is a big-size moth, the adults having a wing span of 75-100 mm and larvae a final length of 80-110 mm. Adults and larvae (Figs. 410, 411) have the characteristic appearance of members of the Sphingidae. The larvae eat the vine leaves, but seldom cause considerable damage, because the population density of this species is usually low. On the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Figs. 410-411. *Theretra alecto*. 410.Adult. 411.Grown larva (photo B.I.K.).

island of Chios, in vine trellises, erosion of leaves was observed mostly in August-September (B.I. Katsoyannos, unpublished data).

Wasps and hornets (Hymenoptera, Vespidae)

They are medium to large-size insects. The body of the adults of

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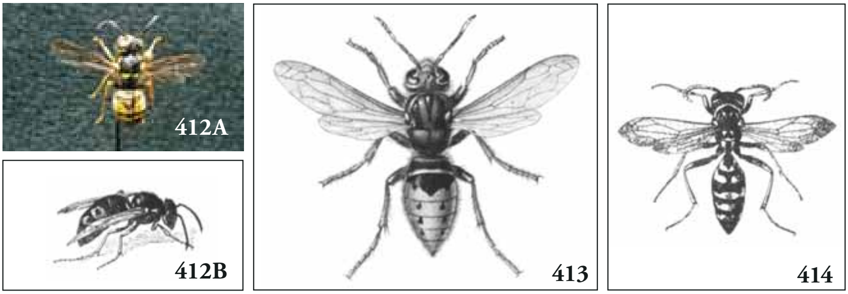

Figs. 412-415. Wasps. 412. *Vespula germanica* A. Adult in dorsial view, B. In side view (photo B.I.K. and Sta. Firenze respectively). 413. *Vespa crabro* natural size. 414. *Polistes gallicus* magnified by one third (Sta. Firenze). 415. Injury to grape by wasps (Rumbos 1987).

most species is black or dark brown, with yellow spots or stripes (Figs. 412-414). They possess a sting.

Life history and damage. The species causing damage to grapes and other fruits live in communities. Every community includes one fertilized female called “queen”, males, and many more workers. In areas with cold winters, each community lives for only one growing season, from spring to autumn. The males and workers die in autumn, while the fertilized females overwinter in protected sites and each of them creates a new community the following spring.

The adult wasps eat insect honeydew, nectar, fleshy fruits, and especially ripe fruits. They also take pieces of fresh or slightly stale fish, flesh of various vertebrates, or entire insects, to feed their larvae. Some species take back, through trophallaxis, from their larvae, part of the proteins they offered them. The proteins are returned broken down. The larvae develop in cells which resemble in shape those of the honeybee, but are constructed with wood or bark that the adults

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chew and mix with saliva. The shape, size, number and pattern of larval cells within the nest varies with the species of wasp. Some species such as *Vespa orientalis, Vespula vulgaris, V. germanica* (Fig. 412), and *V. rufa,* make their nests in the soil, especially at steep sites, in cracks of walls, or in wall corners under roofs. Other species such as *Vespa crabro* (Fig. 413) make their nests in trunk cavities of old trees and in holes or cavities inside abandoned old buildings, whereas *Vespa norvegica* and species of *Polistes* (Fig. 414) in bushes.

Wasps are generally useful, because they eat the flesh of cadavers of various animals before they rot, and they catch a considerable number of harmful insects, especially Diptera and Lepidoptera, to feed their larvae. Certain species become occasionally harmful, when they sting humans, eat ripe or almost ripe fruits, remove bark from trees or shrubs to construct their nests, or kill honeybees to feed their larvae. Consequently, wasps should be controlled only when they are likely to cause injury. The presence of a wasp nest on an outer wall or the roof of a house, in a tree trunk cavity, in a shrub or in the soil near habitations does not necessarily mean that we will have annoyance or injury. Furthermore, we should not kill wasps or destroy their nests in autumn. At that time of year the wasps will soon die and their nests will not be reused. Yet, when a nest is near a street, or a passage of children or of domestic animals which are likely to disturb the nest and be stung by the wasps, control is necessary. Control is of course necessary when the wasps start removing bark of useful plants, or when we see a large number of wasps on bark of useful plants and on fruits nearing maturity (Fig. 415), or when wasps become annoying in recreation or other open air localities frequented by people.

The oriental hornet, *Vespa orientalis* is of large size, 20-26 x 5-7 mm, and one of the most harmful species of the wasp family. Its workers eat ripe grapes, other fruits, remove bark from fruit trees and other trees, invade honeybee hives to eat honey and kill honeybees. Its sting is painful, and in many people causes swelling which lasts up to a few days. Persons allergic to the toxin of the sting of wasps and bees may need immediate medical care in order to avoid undesirable consequences, especially if stung by *V. orientalis* or *V. crabro* (Fig. 313). Another large species of hornet, *Vespa velutina* Lepeletier, of asiatic origin which has been recorded in a number of localities of France and recently of Spain, is another honeybee forager, therefore, harmful to apiculture (Lopez et al. 2011).

Control. The best way is to find the nest and destroy the wasp

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community there. Our intervention should be done in late evening or at night. At that time the wasps are in or on the nest, and their activity is limited, thus the probability of stinging us is limited. If we are holding an electric torch, it is advisable to keep it to the side, away from our body, so that the wasps do not come on us if they fly towards the light. Persons allergic to wasp sting should not approach the nest. We spray or dust the nest or its entrance, as well as a small area around it with a suitable contact insecticide, organophosphorous, pyrethroid or other, of small toxicity to warm-blooded animals and man. Formulations for domestic use in cans under pressure (aerosol bombs) are also suitable. After applying the insecticide, it is advisable to cover the nest entrance with soil or mud. When the nest is in the soil and we do not have, or do not want to use, an insecticide, we can introduce gasoline in the entrance and cover it with mud or otherwise plug it. The gasoline fumes kill the adult wasps but not their pupae. Therefore, the next day we should dig out and destroy the nest mechanically. Otherwise, the pupae will become adults in a few days. Nests that are exposed (in rocks, walls, trees, bushes etc.) can be destroyed by fire. We burn the nest with a torch underneath. If the nest is in a tree trunk that we want to save, the introduction of burning sulfur has been suggested.

When the detection of the nests is not possible or practical, control is done with poison baits, with or without traps. The bait is meat, meat product, liver, clotted blood, dog or cat food with meat odor, or better with fish odor. We mix the bait with a proper insecticide. For certain species of wasps eptyl butyrate and octyl butyrate are very attractive. Traps of the cage type with conical entrances catch and kill only adult wasps. A better way is to use cages having mesh openings allowing the entry and exit of the wasps. Thus, the wasps take pieces of poisoned bait to their nest, feed their larvae with and also contaminate other wasps, causing a gradual annihilation of the colony. In Israel, in non-residential areas, a commercial formulation of fibronil at 0.25% active material in meat baits proved effective in killing families of *V. orientalis* (Klein and Zarabi 2003). We can reduce substantially the population of this hornet by placing traps at sites where those hornets drink water, in early spring, to catch and kill the overwintered queens before they form nests.

In certain areas fruits are wrapped in paper or tulle bags to protect them from wasps. If necessary, the vineyard is sprayed with an insecticide of very short residual action, of those permitted up to

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a few days before harvest. On the contrary, to protect the bark, a long-residual action insecticide is needed. In general, a combination of various means of control is suggested. To be effective, such means should be applied over a large area, and early (in spring or early summer) before the wasp population reaches high densities which cannot easily be brought under control.

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A few insects of common amenity trees and shrubs

Many insects that infest trees grown for their fruit, also infest related trees or shrubs which are used for shade or ornament along streets, in parks, or in home gardens and yards. Other species infest preferably or exclusively amenity trees or shrubs. Some insects of these categories occurring in Greece and some other Mediterranean countries are: On *Ligustrum* sp. the moth *Clepsis unifasciana* Du., on *Viburnum* sp. the whitefly *Aleurodes jelineki* Frauenfeld and the scale insect *Lichtensia viburni* Signoret, on the fragrant jasmine, *Jasminum officinale grandiflorum,* the moth *Palpita unionalis* (Hübner), on *Syringa vulgaris* the moths *Gracillaria syringella* F. and *Leucoptera laburnella* Stainton, on *Nerium oleander* the aphid *Aphis nerii* B. d. Fonsc., the scale insect *Aspidiotus nerii* (Bouché) and the moth *Deilephila nerii* (L.), on *Evonymus* sp. the scale insect *Chionaspis evonymi* Comstock, on rose the aphids *Macrosiphon rosae* (L.), *Myzaphis rosarum* Kaltenbach, *Myzus persicae* (Sulzer), *Aphis gossypii* Glover and other polyphagous aphids, the scale insect *Aulacaspis rosae* (Bouché) and various other polyphagous scale insects, the beetle *Cetonia aurata* L. and other beetles such as *Otiorrhynchus* spp., the moths *Hedya ochroleucana* Froel., *Croesia bergmanniana* L., *Platyptilia rhododactyla* Schiff. and *Carposina scirrhosella* H.-S., the hymenopterans *Rhodites rosae* (L.), *Arge rosae* (L.), *Arge pagana* Panzer and other species of the same genus, on laurel the psyllid *Trioza alacris* Flor. and the scale insect *Aonidia lauri* (Bouché), on elm the beetle *Galerucella luteola* Mueller and the aphid *Eriosoma lanuginosum* Hartig), on pines the scale insect *Marchalina hellenica* (Gennadius) and the moths *Thaumetopoea pityocampa* Schiffermueller and *Thaumetopoea wilkinsoni* Tams., on palms the beetle *Rhynchophorus ferrugineus* Olivier and the moth *Paysandisia archon* (Burmeister), and on plane trees the hemipteran *Corythucha ciliata* (Say).

The life history and control of some of the above insects are given in other parts of this book (see index). Herebelow we treat only 8 species that infest palms, pine trees, plane trees, oleanders, or roses in Greece. Many readers of this book are likely to meet these pests around their homes. This is why they are included in the book.

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Homoptera

- *Aphis nerii* Boyer de Fonscolombe, Aphididae
- *Macrosiphon rosae* (L.), Aphididae
- *Marchalina hellenica,* (Gennadius), Margarodidae
- *Corythucha ciliata* (Say), Tingidae

Coleoptera

- *Rhynchophorus ferrugineus* Curculionidae

Lepidoptera

- *Thaumetopoea pityocampa* (Schiffermueler), Thaumetopoeidae
- *Thaumetopoea wilkinsoni* Tams., Thaumetopoeidae
- *Paysandisia archon* (Burmeister), Castniidae

Aphis nerii **Boyer de Fonscolombe** *(A. asclepiadis, A. calotropidis, Anuraphis nerii, Cerosipha nerii)* **(Homoptera, Aphididae)**, comm. **yellow oleander aphid, yellow nerium aphid**

Adult. The apterous parthenogenetic female, which is 2-2.5 mm long, is recognizable by its pretty golden yellow body color. The antennae, legs and cornicles are shiny black (Balachowsky and Mesnil (1936). The winged form has antennae, thorax and legs black, the rest of the body being yellow.

Host plants. According to Bodenheimer and Swirski (1957) it lives on Apocynaceae and Asclepiadaceae. It may also be found on other species of plants on which a complete annual cycle is not expected to occur. Usually it infests the oleander (*Nerium oleander*). Its distribution is wide, including southern Europe, the Middle East, North and South Africa, U.S.A., and other regions.

Life history and damage. It lives in usually dense colonies near the tips of shoots of the oleander or other plants. It is found also on the lower surface of leaves, especially tender ones. In its colonies, except the abundant wingless adults and larvae, winged adult individuals are also seen (Balachowsky and Mesnil 1936). In Israel it reproduces only parthenogenetically and is most abundant in spring, when it heavily attacks oleanders. In autumn it is less abundant, in summer its population is low, and in winter the level of its population depends on climate (Bodenheimer and Swirski 1957). In the Mediterranean region it survives the whole year, and seems to reproduce parthenogenetically.

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Control. See section on aphids and their control in the chapter on insects of pome fruit trees.

Macrosiphon rosae **(L.)** (*Aphis rosae, A. scabiosae, Siphonophora rosae*) **(Homoptera, Aphididae)**

It is the major and most common of the aphids that infest rose bushes (*Rosa* spp.) in Mediterranean ornamental gardens and front yards. It is found in all parts of the world where indigenous *Rosa* spp. exist. The apterous female is 4 mm long, greenish, often light, with black siphons. The alate has dark brown head and thorax, greenish abdomen with small brown dots, and is 3.5 mm long. In spring and in late summer and autumn it infests the tender parts of rose and other host perennials. Infestation inhibits the normal growth of new vegetation and flowering. In summer it goes to herbaceous plants such as *Dipsacus, Scabiosa* and *Valeriana* (Silvestri 1939).

Marchalina hellenica **(Gennadius)** *(Monophlebus hellenicus)* **(Homoptera, Margarodidae)**, comm. **cottony pine scale**

Gounari and Hodgson (2011), citing respective work by Hodgson and Foldi (2006) place this species in the family Marchalinidae.

Adult. It is mainly parthenogenetic, males having been reported as rare. In contrast to subsequent researchers, Vayssière (1923) found no ovisac in the adult females he examined. According to Isaakides (1936a) the female body is yellow, cylindrical, and 8 mm long. Marotta and Priori (1992), for individuals from Ischia, give body dimensions 7-11 x 3.5-5 mm, antennae with 11 articles, and mouth stylets absent. Bacandritsos et al. (2004) report average dimensions of 7.1 x 3.5 mm of adult females grown on pine on mount Parnis north of Athens. Newly formed adults are bare. They soon settle in bark cracks and crevices to lay their eggs, and start secreting abundant cottony wax filaments which cover the female body and the eggs underneath (Figs. 416, 417). This wax protects from harmful weather conditions and natural enemies, and remains on the bark long after the insect has changed site or died. For the morphology of adult males see Hodgson and Foldi (2006).

Egg. Yellow, oval, with a smooth surface, 0.8-1 mm (Marotta and Priore 1992).

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Figs. 416-417. *Marchalina hellenica.* 416.Adults and waxy secretions (cottony wax) on a pine branch. 417.Cottony wax on pine trunk (photo B.I.K.).

Larva. Silvestri (1939) gives drawings of the L3 and states that it resembles the adult female but has fewer antennal articles. The adult has 11 articles and atrophied mouthparts. Some subsequent authors reported that there are only two larval instars in the female. Marotta and Priori (1992) ascertained that there are 3 instars. They also gave a key to those instars and to the adult female. Their larvae from Ischia had the following general characteristics: L1 body oval, yellow, 1-1.5 x 04 -06 mm. Antennae with 6 articles. Mouth parts well developed, the rostrum reaching the bases of the mesothoracic legs and the stylets being much longer than the body. L2 body oval, yellow, covered with a white wax secretion, 2-3 x 0.9-1.2 mm. Antennae also with 6 articles and stylets as long as the body. L3 body elongate oval, yellow, covered with a dense and abundant cotony white wax secretion, 3-8 x 1.5-4 mm. Antenae with 9 articles, stylets less long than the body.

Host trees. Until recently it was recorded only on various species of pine, such as *Pinus brutia, P. halepensis, P. leucodermis, P. maritima P. nigra, P. pinea,* and *P. sylvestris* (Kailidis 1991, Marotta and Priori 1992, Gounari 2003-2004 and references therein). Fairly recently Bacandritsos et al. (2004) reported its establishment also on the fir *Abies cephalonica* on mount Helmos in the Peloponnese, after artificial infestation. The insect occurs in Greece, Turkey, Israel (Kailidis 1991), the Italian island of Ischia (Fimiani and Molino 1994), southern Bulgaria and up to northern Caucasus (Avtzis et al. 2013).

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Life history and damage. It completes one generation per year. On pines the female overwinters as last-instar larva. The larvae introduce their mouthparts in the bark and suck the sap of pine trees. They can walk, and sometime in autumn move to their overwintering shelters in crevices of the bark. Silvestri (1939) mentions that, as a rule, the females oviposit in May and the newly hatched larvae search for fissures of the bark where to settle and feed. According to Babandritsos et al. (2004), on unspecified species of pine trees on mount Parnis, north of Athens, the female overwintering stage lasted from October to March, the adult in March and April, oviposition took place in April, and the first- and second-instar larvae covered the period from May to October. According to Gounari and Hodgson (2011), the male larva is in the third instar (prepupa) in early winter, pupates sometime in January to early February, and becomes adult in early March.

Gounari (2003-2004) studied this insect for three years in a pine wood of 15-year old *Pinus brutia* in the outskirts of Thessaloniki, coastal northern Greece. On those trees, the third-instar larvae sucked sap and excreted abundant honeydew in early spring. In late March to mid-April their feeding slowed down and they molted to adult females. The adult females do not possess proper mouthparts and do not feed. Consequently they excrete no honeydew. Their body is soft and shiny. Most of them dispersed towards lower parts of the trees, each searching for a suitable protected site to settle then oviposit. Such sites are fissures and crevices of the bark, preferably not exposed to strong light. The remaining lower percentage of females settled at or near the sites they molted to adult. In one year the adult dispersing phase started in late March and ended in late May, being massive in April, while in a following year it started in late April and ended in late May, being massive in May. After it has settled, the female begins to secrete long wax filaments, forming a white ovisac which covers its whole body and in which approximately 200-250 eggs are laid. Ovisacs containing eggs were mostly recorded from mid-April to late May in two of the years and from early May to early June in the third year of observations. By the end of May all females had died. Crawlers appeared in substantial numbers in mid-May and in mid-June in the first two and the third year respectively. In Attica, eastern central Greece, adults begin to be formed in March.

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Observations by Bacandritsos et al. (2004), in a fir forest of southern Greece at an altitude of 2000 m, show that the insect on the native fur *Abies cephalonica* Loudon overwinters as L1. This instar was observed from August to April, the last-instar larva in May and early June, and the adult female in June. Oviposition occurred in June and incubation of the eggs lasted through July. This different seasonal development on fir, in contrast to pine, we feel needs further study of the seasonal development of the population growing on fir.

Margaritopoulos et al. (2003) Used random amplified polymorphic DNA (RAPD) analysis of individuals from six populations of *M. hellenica* collected in northern, central and southern mainland Greece, on two species of pine and one species of fir tree. An important differentiation was found of those insects from fir in southern Greece, and to a lesser extent from pine trees in central and northern Greece.

The honeydew the larvae excrete in spring is fed on by honeybees that produce from it the pine honey. This pine honey accounts for approximately 60-65% of the total honey produced in Greece (Avtzis et al. 2013). Several years ago, the Greek Ministry of Agriculture encouraged honeybee growers to introduce the pine scale to previously uninfested areas. Unfortunately this was done also in parks within and trees along streets of the city of Athens and suburbs. The population outbreak of the insect that resulted caused worry to the citizens who were annoyed by honeydew dropping on passers-by and parked cars. Also views were expressed that this pest might weaken and even kill certain pine trees.

The loss of sap because of larval feeding reduces the vigor of pine trees measured as crown transparency or reduction of wood production. The degree of weakening of an infested tree depends on the species, the available soil moisture, and possibly other factors. In some places infestation of pine trees was found to reduce the width of the tree's annual rings (Yesil et al. 2005, as cited by Petrakis et al. 2011). Opinions vary as to whether this insect can kill pine trees. There are statements that certain trees weakened by this scale insect become more susceptible to heavy infestation by bark beetles, and thus are indirectly led to death (Petrakis et al. 2006). Work by Mita et al. (2001) shows that chemical and morphoanatomical changes occurred in infested *Pinus halepensis.* These authors present the hypothesis that the insect affects the volatiles composition of the host tree, or its ability to react histochemically, or its water balance, so that population outbreaks may follow of bark- and cambium-feeding insects that are

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able to get established in the pine tree. In addition to weakening the trees, the abundant honeydew excreted by the scale insect falls off the trees like rain drops to the ground, soiling sidewalks, parked cars, and making sitting under pine trees unpleasant if not impossible. In urban and suburban areas this is especially unpleasant during the period of maximum excretion (March-April). Honeydew also favors the development of sooty mold fungi, which darken the soiled surfaces. In 2008, in a suburb northeast of Athens, honeydew started dropping on sidewaks already in late February and was abundant in mid-March. Petrakis et al. (2010) investigated the relative importance of several eco-physiological variables on the injury caused to pine trees in eight localities of Attica. They found that the most important variables were the population density of the insect, the tree crown transparency, the mean distance between trees, and the quality of the habitat.

Isaakides (1936a) mentions as natural enemies of the cottony pine scale a dipteran *Leucopis* sp., and the coleopteran *Dasypes flavipes*, the larvae and adults of which eat all life stages of the scale insect.

Control. In cities and towns a spray with water, with a high-pressure sprayer, is recommended in May. At that time some adults search for oviposition sites, and some have started to oviposit. This spray causes a portion of the adult population and many of the eggs still in their ovisacs to fall off the tree. Current recommendations issued by the Greek Ministry of Agriculture include a spray of the trees in April against the dispersing adults, and a second one between the 5th and 20th of June against the newly hatched larvae. The June spray should preferably be done when approximately 65% of the larvae have hatched from the eggs. As safer for the public, summer oil emulsions are preferred to synthetic insecticides for both sprays. In addition to issuing control recommendations, the pertinent authorities should not only stop encouraging, but also forbid beekeepers to further introduce this scale insect into parks in and around cities and towns.

Corythucha ciliata **(Say) (Hemiptera: Tingidae)**, comm. **sycamore lace bug**

Adult. The adult is approximately 3-3.5 mm long. Most of the body is dark. The pronotum is yellowish and has a pair of side, kidney-shaped leaf-like reticulate expansions and a median vesicated process. The forewings are subquadrangular, reticulate, light-colored, transparent,

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and each has a proximal vesica which is grobular and more or less smoky towards its internal margin (Servadei et al. 1972) (Figs. 418, 419). For pictures of adult and preimaginal stages, as well as infested plane trees, see also Arzone (1975), Tzanakakis (1999), and Avtzis et al. (2013).

Host plants. In northeastern and northwestern United States this bug, which is of nearctic origin, is a pest of sycamore, *Platanus occidentalis* L., which is its preferred host plant. There it also feeds on ash, hickory and, according to Craighead (1960), also on mulberry. In Europe, since its first entrance in Italy in 1964, its hosts of preference have been *Platanus* x *acerifolia* (Aiton) Willd. and *P. orientalis* L., while such other broad-leaved trees as *Brussonetia papyrifera* and ash have also been reported as able to support it (Servadei et al. 1972). This insect's spread in Europe has been rapid. By 1987 it had spread from Spain eastward to Hungary and to the Balkans (for references see Tavella and Arzone 1987). In Greece its presence was detected in four localities in the northwest of the country in 1988, and by 1999 it had spread to approximately half the country (Tzanakakis 1988, 1999). By now it must occur in most areas of continental Greece.

Life history and damage. There are no data regarding its life history in Greece. In Italy it completes 2 or 3 generations per year, same as in its region of origin, the United States. It overwinters as an immature adult, mostly under loose bark at the basal part of the trunk or in other ptotected sites nearby. In spring the adults walk up to the young leaves, feed, mature sexually, mate and oviposit on the underside of leaves. The larvae feed and develop on the underside of leaves piercing and sucking the contents of parenchymatic cells. The young adults of following generations also feed and reproduce there. In autumn, the young adults descend from the leaves to the trunk or to other neaby refuges where to overwinter. In Piemonte (northwestern Italy), where 2 generations are completed per year, the adults that have overwintered reach the foliage the last 10 days of April and the first ones of May. Those of the first generation are seen from late June to mid-August. Those of the second generation are seen on the leaves from mid-August on, but begin to migrate to their winter quarters the second decade of September (Arzone 1975). More to the south, in the Firenze area, 3 generations are completed. The larvae of the first generation occur from early May to early August, and the adults from late June to the second decade of August. Larvae of the second generation were seen from early July to late August

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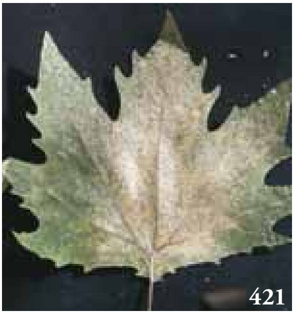

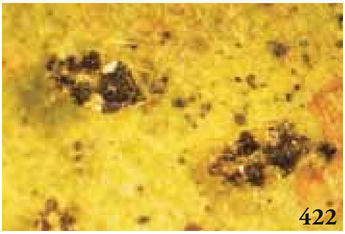

Figs. 418-422. *Corythucha ciliata.* 418.Adult in dorsal view. 419.Adult in ventral view. 420.Left uninfested, and right infested plane leaf. 421.Heavily infested leaf. 422.Two larval exuvia and dark spots on underside of infested plane leaf. (Tzanakakis 1999).

and the adults from early August. Some of those adults migrated to overwintering sites, while the rest matured sexually and gave birth to third generation larvae. For details see Tiberi et al. (1988).

Both larvae and adults pierce and suck the leaf parenchyma. This causes weakening of the tree and a characteristic chlorosis of the leaves. This chlorosis starts at the basal part of the leaf and may expand to almost the whole blade (Figs. 420, 421). On the underside of leaves where the insect lives in colonies, there are usually numerous dark spots or points, due to the insect's excrement and oviposition punctures (Fig. 422). When the insect's population is dense, early leaf drop may also occur. In Italy, the loss of a large quantity of the contents of leaf cells, and especially of chloroplasts, affected adversely the

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growing condition of the trees and the production of wood. Weakening of the trees may also predispose them to attacks by other enemies (Tavella and Arzone 1987). In addition, the adult bugs when disturbed because of shaking of the foliage or of other reasons, abandon the leaves, and land on any surface, even on people, or enter homes. This disturbane of people, according to Arzone (1986), is another factor not to be underestimated. Another undesirable condition affecting humans is the dropping of the insect's feces as minute dark particles, often unnoticed by people, on any surface under infested trees. This soiling of persons and objects should especially concern customers and owners of open-air coffee shops, pastry shops and restaurants (Tzanakakis 1999). There is suspicion that *C. ciliata* is a vector of the fungus *Ceratocystis fimbriata* (Ell. and Halst.) Davidson f. *platani* Walter, and that its punctures may facilitate the entrance into the leaves of another fungus, *Gnomonia platani* (Kleb.), which causes the plane tree anthracnosis (Arzone 1986, Tiberi et al. 1988). *C. ciliata* is considered one of the three most important insects infesting the leaves of plane trees in Italy (Tiberi et al. 1978) and generally very destructive (Tremblay 1981). During the first years of its invasion in Europe, damage to plain trees especially in urban areas was such that the International Organization for Biological Control (IOBC/WPRS) formed the working group "Integrated Control of *Corythucha ciliata*". This group organized two conferences on the subject. The presentations in those conferences have been published in the respective proceedings, and are worth consulting.

Control. Control with insecticides is difficult and has many limitations, mainly because of the height of plane trees and because control concerns inhabited areas. Insecticides have been applied in the following ways: 1) Spraying the trunk and limbs in spring and autumn, with a long residual action insecticide, to kill the migrating adults. The proper time for such sprays is determined after sampling to learn the periods of migrations. In southern Italy each such migration period lasted approximately 2 months. 2) Spraying the foliage. This is recommended for trees along streets, but not very close to human habitations. Proper period is considered the end of hatching of larvae of the first generation. Such period in southern Italy was found to be the month of July. During this month, most of the insect's population consisted of larvae, immature adults, and a few late eggs (Tremblay 1986). The spray liquid should be directed carefully to the lower surface of leaves. 3) Injection of a systemic insecticide in

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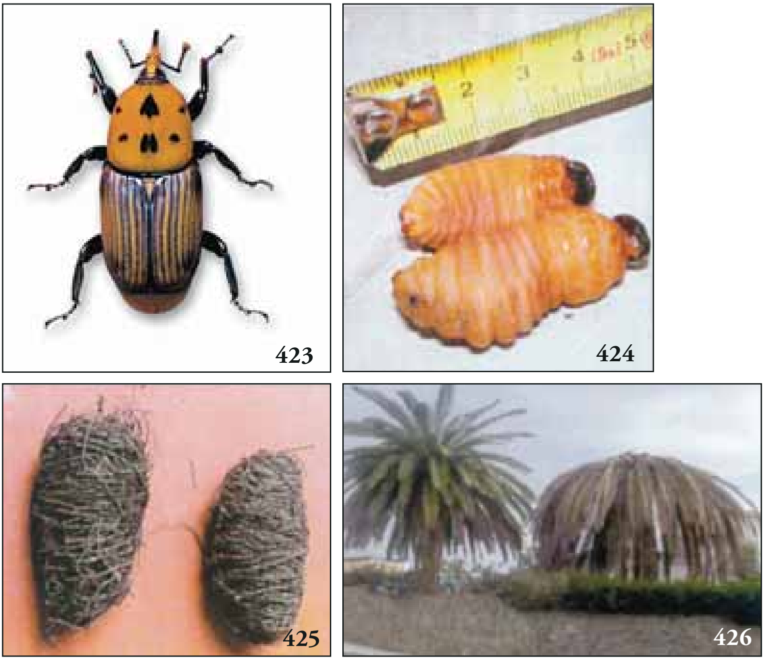
the trunk. It aims at the insecticide reaching the leaves through the vessels of the sapwood. For details of such application and its results see Kovács (1984), Tiberi and Panconesi (1985) and Tremblay (1986). Suggestions on some studies and control measures to be taken against this insect in Greece were suggested by Tzanakakis (1999).

***Rhynchophorus ferrugineus* (Olivier)** (*R. signaticollis, Curculio ferrugineus, Calandra ferruginea*) **(Coleoptera, Curculionidae)**, comm. **red palm weevil, Asiatic palm weevil, Indian palm weevil, red stripe weevil, coconut weevil**

Adult. It is a large weevil, approximately 30-35 mm long and 10-12 mm wide, with a long curved rostrum. Dorsally the body and rostrum



Figs. 423-426. *Rhynchophorus ferrugineus.* 423.Adult (Skenteridis and Tsampouraki-Georgiou 2011). 424.Larvae. 425.Two cocoons. 426.Left healthy, and right killed palm tree. (Kontodimas et al. 2006)

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are reddish brown and the eyes black. The pronotum has a few dark spots which vary in shape, size and number (Fig. 423). The elytra have longitudinal grooves. The dorsal apical part of the male rostrum bears dense brownish hairs. Data and photographs for the diagnosis and distinction between *R. ferrrugineus* and *R. palmarum* are given in OEPP/EPPO (2007). The adults are capable of long flights.

Larva. The neonate one is yellowish-white with a brown head. The fully grown one is of similar color and 50 x 20 mm (Fig. 424).

Pupa. First cream and later brown, enclosed in a pupal case 50-95 x 25-40 mm made of fibers from its host tree (Fig. 425) (OEPP/EPPO 2008a).

Host plants and geographical distribution. This weevil infests most species of palm trees (Arecaceae or Palmaceae), including both feather and fan palms, and is the most important pest of palms internationally **(**Kontodimas et al. 2005-2006, Abbas 2010, and references therein). Among its hosts are the coconut palm, oil palm, sago palm, toddy, royal palm, date palm *Phoenix dactylifera,* and ornamental Canarian palm *P. canariensis,* the last one being quite common in parks and along streets and boulevards of Greece and other Mediterranean countries. The weevil is reported to be able to infest also the sugarcane *Saccharum officinarum* and *Agave americana* (OEPP/EPPO 2008a). *Washingtonia filifera* (Lindl.) and *Chamaerops humilis* L. have been reported as resistant to the weevil (Dembilio et al. 2009). To test the susceptibility to the pest of *Phoenix theophrasti,* a native species of palm occurring only on Crete and a few other Greek islads, adult weevils were caged with seedlings of this palm. All seedlings were infested, and most of them killed by the weevil within 100 days (Kontodimas et al. 2006).

From southern Asia and Melanesia, its region of origin, the weevil has advanced westwards very rapidly since the mid 1980s. In 1985 it reached Saudi Arabia, in late 1992 Egypt, and in1999 was found in Israel and Jordan. In 1994 it was captured in the south of Spain (Ferry and Gomez 2002). The outbreak in southern Spain is threatening the largest palm plantation in Europe, which is rated as a World Heritage Site by UNESCO. According to Ferry and Gomez (2002), the cause of the extensive and rather rapid spread of this weevil has been the transporting by man of infested young or adult palm trees and offshoots from contaminated to uninfested areas. They attribute the introduction of the weevil to Spain with adult

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palms imported from Egypt. At that time, importation of palms from Egypt was not prohibited, and Egypt was the main source of supply of ornamental palms for Spain and some other European countries. These authors give the situation concerning the weevil in Spain and Egypt, and point out the seriousness of this pest and the high risk of its arrival in other countries of the Mediterranean. The weevil has since spread to Cyprus, France, Greece, and Italy (CABI/EPPO 2003). In 2005 it was recorded on the island of Crete, and in 2006 in central Greece and the island of Rhodos (Kontodimas et al. 2005-2006). Infested ornamental palms were recorded mostly near infested palm nurseries. On the northern coast of Crete, the weevil seems up to now to infest preferably the Canarian palm. Traps placed in autumn on palm trees captured substantial numbers of adult weevils in November and December (Aggelakopoulos et al. 2009). By 2013, all Canarian palms had been infested in Crete (E. Angelakis personal communication).

Life history and damage. According to OEPP/EPPO (2008a) the adults are active during day and night, but flight and crawling is generally restricted to daytime. Adults of both sexes mate many times during their lifetime. The oviposition period lasts approximately 45 days during which an average of 200 eggs are laid. The eggs are laid in holes made by the female's rostrum at the base of young leaves, in other parts of the tree, in wounds along the trunk, in peduncles, and even in holes caused by other insects. In date palm plantations, eggs are reported to be laid also at the base of the tree where suckers have been removed for propagation or cosmetic purposes. The incubation lasts a few days. Upon hatching, the larva enters the palm tree and bores feeding galleries and cavities in the interior of it. In palms up to 5 years old, the larvae are found in the bole, the stem or the crown. As palms advance in age, the larvae are generally confined to the portions of the stem close to the growing point. In trees more than 15 years old, the larvae are generally found in the stem approximately 1 m below the crown, in the crown and in the bases of leaf petioles. When approaching full growth, the larvae reach the lower part of the trunk from where they will ultimately reach the outside to pupate. Pupation occurs generally outside the trunk, at the base of the tree, in a case made of brown dry palm fibers (Fig. 425). In general, larvae may be found internally at any part of the plant, including the very base of the trunk where the roots start (Ferry and Gomez 2002). The larval stage lasts approximately 1-3 months, and the life cycle is

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completed in 4 months, depending of the time of year, local climate and species of palm tree. In Egypt, 3 generations are completed per year, the shortest (first) lasting approximately 100 and the longest (third) 130 days. All life cycle stages of different overlapping generations may be present within the same palm tree. Ferry and Gomez (2002) state that, generally, the adult weevils present in a palm tree will not move to another one unless food or oviposition substrate become insufficient.

The injury to the palms is caused mainly by the larvae, which feed on the soft fibers and terminal bud tissues, often destroying the apical growth area of the palm. Usually the injury is visible long after a palm is infested. By the time the first symptoms appear, injury is so serious that generally it results in death of the tree (Fig. 426). This inability to early detect the infestation makes the control of this pest difficult, and the guarantee of pest-free palm trees from infested areas impossible (Ferry and Gomez 2002). Careful observation is needed to see the following signs of the presence of the insect: Holes in the crown or trunk from which chewed up fibers are ejected. A brown, viscous, ill-smelling liquid may also be oozing from the holes. A crunching noise produced by the feeding larvae can be heard when the ear is placed to the trunk of the palm. A withered bud or crown is another sign (OEPP/EPPO 2008a). When infestation has advanced and the tree is beyond repair, there is also wilting or yellowing of leaves. In species of palm such as the date palm and the coconut palm, there is a substantial reduction of the yield and lowering of the quality of the fruits to a point that many farmers have been ruined in a number of countries.

Detection techniques and means are given in OEPP/EPPO (2008a). Among them is an electronic detector that amplifies the noise made by the larvae. Food-baited traps, pheromone traps with an aggregation pheromone and a kairomone, often in combination, have also been used for monitoring, as well as for mass-trapping the adult weevil population.

Kontodimas et al. (in press) give details and many photographs of the symptoms of palm infestation by each of the two borers, the weevil and the moth *Paysandisia archon*. They point out that accurate detection of early infestations is important for the survival of infested palms, because often there are no apparent symptoms of the initial stages of the infestation by both borers. Visual inspection is still the most common method of infestation analysis.

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Control. As the larvae feed inside the plant, killing them is difficult. Both prevenive and curative measures should be taken. Control is usually directed against both the adults before they oviposit, and the larvae before and after they enter the plant. Among the control measures recommended by OEPP/EPPO (2008a and references therein) are: Avoid the transport of offshoots as planting material from infested areas. Destroy promptly all dead or obviously infested palms by cutting, chopping, and burning them, because infested trees constitute focuses from which the weevil will spread further. Avoid injuring the trees to limit suitable oviposition sites. Cut leaves at or beyond the part where leaflets start, to prevent the entry of larvae into the stem. Fill leaf axils with insecticide dusts mixed with sand to prevent entry of the larvae. Drench the upper part of the tree with an insecticide. Inject systemic insecticides in the trunk. Treat cut surfaces of the tree with an insecticide. Apply a suitable formulation of an entomopathogenic nematode. In areas where palms are infected by pathogenic fungi apply fungicides, because diseased trees are more prone to weevil infestation. Mass trap the adult weevils with the proper number of traps releasing the aggregation pheromone and the kairomone, a feeding attractant and an insecticide. For information regarding the placement and servicing of the pheromone traps see respective literature issued by the companies marketing the traps.

Kontodimas et al. (2011) describe ways to remove the weevils from infested palms, to either save some of those trees, or reduce the probability of infestation of uninfested neighboring ones. Melifronidou-Pantelidou (2009) gives the measures taken at that time for the eradication of the weevil in Cyprus, and Nardi et al. (2011) the control measures taken in North-Central Italy according to EU Decision 2007/365/EC.

In the Southern Jordan Valley of Israel, when catches in aggregation pheromone traps showed the presence of the weevil in 1999, a committee composed of experts, extension service consultants, researchers and representatives of local growers' organizations, decided on the measures to be applied during a 4-year period. They included: 1) the declaration of the weevil a quarantine pest and the area of infestation a quarantine area, 2) mass trapping, 3) trunk and soil applications of contact and systemic insecticides in infested plantations, 4) burning heavily infested trees, 5) trunk injections and soil applications of insecticides to infested trees and covering them after treatment with white nets to prevent the escape of adult weevils,

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6) drip irrigation to keep the trunks dry, 7) cutting the offshoots, 8) regular visual surveys and use of specially trained sniffer dogs to early detect infested trees. After 4 seasons of such measures the number of infested trees dropped to zero. It is considered possible that eradication of the weevil was either achieved, or that at least it can be contained and suppressed in that country (Hamburger et al. 2003). This work demonstrates the importance of the immediate detection of this pest, and of multidisciplinary professional teamwork with close contact with growers.

In the Pedion Areos park at the center of Athens more than 400 palms, primarily canary palms, grow. The first infestation by the weevil was detected there in a canary palm in January 2010 (Pontikakos et al. 2015). An IPM program started in the summer of 2010 to control the weevil, with the participation of scientists of the Benaki Phytopathological Institute and staff of two private pest control companies. That program included: 1) Examination of the trees once a month, using special techniques. 2) Classification of all trees depending on the presence or not and the degree of infestation by the weevil. 3) Prompt removal of infested parts through tree surgery, or removal and destruction of whole trees. 4) Injection of insecticides and/or application of entomopathogenic nematodes in the stems of infested trees. 5) Determination of insecticide residues in pieces of stems. 6) Maintenance of a network of pheromone traps in the infested sites to follow the adult population density and activity. Within that IPM program, a four-year experiment aimed at the design, development and implementation of a location aware system (LAS) for the early detection and rapid assessment of the infestation risks by the weevil of palms in urban landscapes. The system can facilitate the treatment process against the weevil by providing analysis of the spatio-temporal characteristics of the weevil problem by accounting for the characteristics of the palms and the available infrastructure. Using mobile/desktop GIS, multimedia content and location-aware tools, the treatments and phytosanitary measures can be applied more rapidly and with more focus and efficiency. Along with the implemented system, a reliable action plan regarding the treatments can be designed to control and eradicate the weevil (Pontikakos et al. 2015). Pontikakos et al. (in press) further describe in several case studies an optimized version of the commercially available location aware system (CPLAS Bytelogic. gr) for integrated management of the weevil on three palm species, *Phoenix canariensis*, *P. dactylifera*

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and *P. theophrasti*. Their system was implemented and evaluated in real time conditions in six localities: two urban parks in Athens and one in Haifa, two date palm orchards in Israel, and a forest of *P. theophrasti* in Crete.

To limit the further spread of the weevil to uninfested areas of southern Europe, Ferry and Gomez (2002) recommend that quarantine regulations be enforced to forbid the import of palms, and especially of adult ones, not only fron north Africa, but even from one European country to another. Therefore, to protect uninfested areas of Greece and other European countries, the best strategy is to exclude this insect altogether, by requiring all imported palms to originate in pest-free areas, or in pest-free places of production of nursery stock (OEPP/EPPO 2008a).

Thaumetopoea pityocampa **(Schiffermueller)** *(Cnethocampa pityocampa)* **(Lepidoptera, Thaumetopoeidae)**, comm. **pine processionary caterpillar, winter pine processionary moth**

This species occurs in southern and central Europe, Asia Minor and certain other countries bordering the Mediterranean. Until fairly recently it was believed to be the only pine processionary caterpillar occurring in Greece. Yet, work by Simonato et al. (2005) showed that on the Greek mainland and on the Ionian islands to the west of the mainland, populations belong to *T. pityocampa*, whereas on Crete and the southeastern Aegean islands of Rhodos and Samos the sibling species *Thaumetopoea wilkinsoni* Tams. occurs. On some other central and northern Aegean islands a race or populations derived from crossing between the two above species is the rule. According to Halperin (1990), *T. wilkinsoni* is one of the many geographical races of the circum-Mediterranean *T. pityocampa* (Den. & Schiff.). *T. wilkinsoni* has long been known to infest pine trees in Cyprus, Israel, and parts of Turkey (Georghiou 1977). It lives and infests pine trees in ways similar to those of *T. pityocampa.* We give below information only for *T. pityocampa.* For *T. wilkinsoni* see Halperin (1969, 1990a, 1990b) and references therein.

Adult. The male has a wing span of 30-35, and the female 40-45 mm. The forewings are grey with darker cross lines, and the hindwings whitish with a dark spot in their posterior margin. According to

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Kailidis (1991) the female head and body are covered dorsally with many grey-brown hairs. The female abdomen is light brown, with a tuft of scales apically, which are used to cover the egg masses. The color of these scales varies with the region from silver grey or brownish to reddish.

Egg. Many eggs, usually 160 to over 200, are laid in a cylindrical cluster which surrounds usually 2 to 4 leaves (needles) over a length of 20-25 mm (Fig. 427). In a locality of northern Greece approximately 67% of egg cylinders were each around 2 leaves and 22% around 4


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Figs. 427-431. *Thaumetopoea pityocampa.* 427.Two egg cylinders (masses) covered with scales around pine leaves (needles). 428.Pine trees bearing many larval nests. 429.Some larvae on the surface of a nest. 430.A larval nest in a heavily defoliated part of a pine tree. 431.Fully grown larvae walking in procession on the ground in search of a suitable site to enter the soil (photo B.I.K.).


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leaves of *Pinus halepensis* (Kalapanida-Kantartzi 2005). Less often, the egg cylinders surround slender twigs. The cylinder of eggs is covered by the laying female with scales from her abdomen.

Larva. The first-instar larva is 2.5-3 mm long, with a black head and a hairy brown-yellow body. The fully grown larva is 30-40 and sometimes up to 50 mm long. On the dorsal side it is grey to dark brown and on the ventral one light brown. It bears long orange or brown hairs and short reddish or yellowish urticating hairs (Fig. 431).

Host trees. Species of pine (*Pinus brutia* Ten., *P. halepensis* Mill., *P. maritima* Lam., *P. nigra* Arnold, *P. pinea* L., *P. radiata* Don., *P. sylvestris* L., *P. pinaster* Ait. and other). In exceptional cases and only to a limited extent, the larvae may infest certain other coniferous trees such as species of fir (*Abies*), *Juniperus, Cedrus, Pseudotsuga* and *Larix* (Kailidis 1991). According to OEPP/EPPO (2004), in order of preference by the moth are species of *Pinus (P. nigra* var. *austriaca, P. sylvestris, P. nigra* var. *laricio, P. pinea, P. halepensis, P. pinaster, P. canariensis)* followed by *Cedrus atlantica* and finally *Larix decidua.* This order of preference does not hold for Greece, where *P. pinea* is much less preferred than *P. halepensis (see below).*

Life history and damage. It completes generally one generation per year, but part of the population may complete a generation in more than one years (see below). It overwinters as an active larva on the tree. The larvae are active in the cool and cold seasons of the year (autumn to spring). The young larvae hatch in autumn. They live in groups, each group including those from the same egg mass. The young larvae stay one near the other and at first eat part of leaves. Later, as they grow, they consume entire leaves (needles). With silk threads they secrete, each group of larvae weaves a nest at the apical or near the apical part of a shoot or twig. The weave of the nest is at first loose (Fig. 429), and later, as the larvae grow, becomes dense and the nest larger (Fig. 430). On and in the nest are abundant granular feces. The larvae enter the nest to protect themselves from rain or when they do not feed. During their first stadia they feed at daytime, but later, during the last stadia they come out of the nest and feed at night. According to N. Avtzis et al. (2013), the larvae of a given group during their first stadium may construct up to 5 nests on the same tree. According to the same authors, a large nest may contain fifth-instar larvae from more than one initial group (egg mass). When the larvae have virtually defoliated the tree they were born on,

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therefore, exhausted the available food (Fig. 430), they may go to a neighboring tree. When walking, one larva follows closely another, as if in a procession. Hence this insect's common name "processionary caterpillar".

Upon full growth, the larvae, one behind the other on a line (Fig. 431), walk down the trunk to the ground and continue to walk on the soil surface until they find a suitable site to enter. Such is usually a site with loose soil and without dense vegetation. For details on the way each group of grown larvae moves down from the tree to the ground and enters the soil, see Avtzis et al. (2013). The larvae enter the soil at a depth of 5-10 cm, and each spins a cocoon in which to pupate. Depending on the area, year, and species and condition of pine, larval growth is completed from mid January to April. In a northern suburb of Athens, the senior author observed a procession of fully grown larvae walking down the trunk of an irrigated *Pinus maritima* tree in late January 2000, whereas grown larvae in procession from nearby non-irrigated *P. brutia* in mid-February. In 1984, in the *Pinus brutia* forest in the outskirts of Thessaloniki, the fully grown larvae began leaving the trees on 10-15 April (Markalas 1989). For individuals with an annual life cycle, the pupae remain in the soil for 3-7 months, whereas for those with prolonged diapause for 1-4 additional years (Markalas 1989 and references therein). Without specifying the localities of northern Greece, Avtzis (1997) mentions that in most years hatching of the young larvae from the eggs started in mid-September and lasted from a month to a month-and-a-half. In only one year did it last from early to late October. Sandy and loose soil were preferred by the fully grown larvae as a pupation site in contrast to compact soil covered with dry pine leaves. The adults emerge from the soil in late summer or early autumn and, after mating, the females oviposit preferably on the highest shoots of the trees. Incubation lasts approximately 3 to 4 weeks.

Seasonal development varies with altitude and latitude. For example, in a park within the Athens city area, male moths were captured in pheromone traps from mid-August to the end of October, with most moths captured from mid-September to mid-October. In the Italian Alps adult emergence occurs in July, whereas in the southern Apennines in September (Masutti and Battisti 1990). Presence of adults for 1-1.5 month, and a single population peak, are typical of increasing populations, while a longer adult emergence period of 2-3 months with 2 or 3 peaks characterize declining populations of

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this moth (Masutti and Battisti 1990). On the other hand, Halperin (1969) states that prolonged diapause seems to be typical of the Thaumetopoeidae, and also occurs in *T. pityocampa.* In Israel he found the estival pupal diapause of the related *T. wilkinsoni* to last up to 6 years or longer. This caused difficulties in eradicating this moth in that country. For how long can diapause last in part of Greek populations of *T. pityocampa* remains to be found.

Larval weight and rate of larval development in caged shoots of five species of 15-year-old pine trees was measured over 4 years in northern Greece by Avtzis (1986). The fastest development and heaviest larvae were obtained on *P. radiata,* an introduced species, the larvae completing growth in early February. Lighter larvae and completion of development a month later were obtained on *P. brutia, P. halepensis* and *P. maritima,* whereas the lightest larvae and latest completion of larval development (50% in early May) occurred on *P. pinea.* Larval mortality was also highest on *P. pinea,* a species of pine known to be resistant to this insect. If other species of pine are nearby, nests of the caterpillar on *P. pinea* are rare. On *P. pinea* the nests remain small, indicating limited larval growth and resulting in limited injury to the tree. Given the choice, moths laid preferably on *P. brutia* and *P. radiata* and avoided *P. pinea* (Avtzis 1997). Papademetriou et al. (2007) developed a laboratory arena where they tested the feeding preference of third- and fourth-instar larvae in the presence of terpenoid extracts from needles of fifteen species of pine. Using a preference model they developed, they interpreted the role of certain of those terpenoids in various steps of the preference and feeding procedure.

In certain years full defoliation of pine trees is caused by the larvae (Figs. 429 430), but seldom is repeated for a few or more consecutive years so as to kill the trees. Yet, tree growth can be reduced considerably because of defoliation. In Italy, complete defoliation of the Austrian pine, *Pinus nigra* Arnold, by the processionary caterpillar induced in the following years a deterioration of food quality and a reduction of food quantity for the larvae. This seemed to be important in the collapse of the insect's population after the outbreak. Such tree reaction may partly explain the cyclic occurrence of outbreaks of this moth (Battisti 1988). In addition to the identity of this moth, whether *pityocampa* or *wilkinsoni,* a factor to consider in interpreting its population changes is the occurrence of prolonged diapause.

Larvae of the 4th and more so of the 5th (last) instar possess

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urticating hairs on 8 abdominal segments. These hairs, studied by Lamy (1990), are hollow inside and carry pointed spikes directed distally. There is no hole or pore in the hair. It is virtually a bulb which must be broken, e.g. in human skin, in order to release the urticant. One of the soluble proteins of the bulb's urticating substance has been named thaumetopoein. For the urticating effect to be expressed, penetration of the hair in the skin, followed by breaking of the hair to release the thaumetopoein are needed. This produces a histamine-liberating effect and accounts for the symptomatology induced by the caterpillar, known as erucism. Conjunctivitis, sometimes keratitis, and even uveitis can be associated with contact dermatitis. In certain individuals, asthma and anaphylactic shock require admission to an intensive care unit (Lamy 1990). Contact dermatitis is common in children playing in school yards under pine trees when caterpillars are fully grown, and especially during the period the caterpillars abandon their nests and proceed along the tree trunks to the soil.

Control. In a few and relatively short trees, timely collection and burning of the nests in autumn is recommended. Sprays with microbial or chemical insecticides should be done soon after most larvae have hatched, and before most of them have grown beyond the second instar. Depending on the area, locality and species of pine tree, the proper time is the month of October. During this period the larvae have hatched from the eggs, and most of them have not grown beyond the second instar. In a suburb of Thessaloniki, on 20-year-old trees of *P. brutia,* on October 24, Avtzis (1983) had 20% of the larval population in L1, 70% in L2 and 10% in L3. In addition to formulations of *Bacillus thuringiensis* which are to be preferred, good results have been obtained in various countries with organophosphorous, carbamate or chlorinated hydrocarbon insecticides and certain insect growth regulators, sprayed from the ground or the air. The repeated use of insecticides of a given chemical family, is known to favor the development of resistance in many species of insect to members of that family of insecticides. In Israel, the susceptibility to *Bt* was found to differ between populations of *T. wilkinsoni* treated intensively, and less frequently (Gindin et al. 2007). Roversi et al. (2010) give details on the control of outbreaks of this moth and of other urticating Lepidoptera with aerial sprays of *Bacillus thuringiensis.*

In a two-hectar section of a pine park within the Athens city area, the mating disruption method was applied (Michaelakis et al. 2011). In the treated section the number of male moths captured in

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pheromone traps was very low until mid-September, in contrast to the neighboring control part. Yet, in October, there was no difference between the treated and the control part.

For details on the life history and control of this insect in Greek, see also Kailidis (1991) and Kailidis and Markalas (2009), for control also Avtzis (1983, 1984), and for details in mechanical control Avtzis (1980). Planting of *P. pinea* should be recommended wherever possible, especially in city parks, along streets, and around human habitations, wherever climate, soil type and possibility of irrigation allow *P. pinea* to grow well.

Another species of the same genus, *T. pinivora,* is reported to have a more northerly range and to be very similar to *T. pityocampa* (OEPP/EPPO 2004). It differs in life history, overwintering in the egg stage on the tree, and the larvae aggregating freely near the pine needles where they were born.

Paysandisia archon **(Burmeister)** (*Castnia archon, C. josepha)* **(Lepidoptera, Castniidae)**, comm. **castniid palm borer**

This moth is another important pest of trees of the palm family, which was introduced to Greece fairly recently with infested palm trees. It was recorded in the last few years in Crete and eastern central Greece (Vassarmidaki et al. 2006), the Peloponnese, the islands of Zakynthos (Zante), Euboea, Syros, Tinos, and Antiparos (Grigorakou and Christofilakos 2011, Papaioannou et al. 2011), and the eastern Aegean islands of Lesbos and Chios (Katsikogiannis et al. 2011). Among its reported hosts are species of *Butia, Chamaerops, Latania, Livistona, Phoenix, Sabal, Trachycarpus*, *Trithinax* and *Washingtonia*. It is of south American origin, and has been recorded also in France, Italy, Spain and the United Kingdom (Vassarmidaki et al. 2006 and references therein).

Adult. It is a large moth with a wing span of 9-11 cm. The body is brown. The forewings are greenish brown with a blackish brown median band. The hindwings are orange with a wide transverse black band, containing 5 or 6 white cells (Sarto i Montes and Aguilar 2005, as given in OEPP/EPPO 2008b). According to another description, the hindwings are orange red with a narrow black margin. A large dark central spot is interrupted in the middle by a white band with 6 cells (Fig. 368). The antenna has a characteristic apical hook (Reynaud et al. 2002). Details on morphology and very good color photos of all

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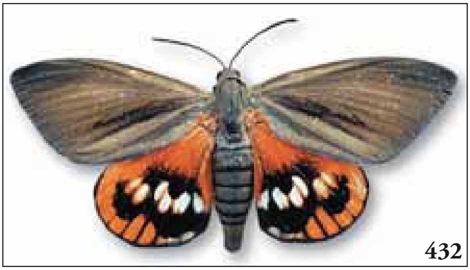

Figs. 432-433. *Paysandisia archon.* 432.Adult (Skenteridis and Tsampouraki - Georgiou 2011). 433.Larva (Psirofonia and Niamouris 2013).

stages of the life cycle and of cocoons are given in OEPP/EPPO (2011).

Egg. It is 5 mm long.

Larva. It is whitish with brown head and prothoracic shield, and the second thoracic segment larger than the rest (Reynaud et al. 2002) (Fig. 369). When fully grown it has dimensions up to 9 x 1.5 cm. The pupa is light brown, up to 5.5 cm long, in a cocoon of plant fibers and sawdust. For morphological characters to identify all life stages, and color photos of them, see OEPP/EPPO (2011).

Life history and damage. According to data from Spain by Sarto i Montes and Aguilar (2005) (taken from OEPP/EPPO 2008b), the adults appear in mid-May and disappear in late September, with a population peak in June and July. In Cyprus, adults were captured from the end of May to the end of July (Vassiliou and Kitsis 2013). The eggs are laid within the fiber webs closest to or within the palm crowns (apical parts). Some larvae overwinter once and some twice, this suggesting a univoltine or semivoltine life cycle. The larvae erode leaves of the tree top and bore long galleries in the trunk. This may lead to ultimate death of the tree. Larval feces, resembling sawdust are seen at the infested tree top and/or the trunk, and nibbled leaves make the infestation easily detectable. Deformation and abnormal twisting of trunks and drying of the palm, especially of the core leaves also occur. In the European countries mentioned above, the injury to the palms may be serious, especially in palm nurseries but also in plantations and amenity trees. By contrast, in South America this moth does not cause serious damage.

Control is difficult because of the endophagous habits of the larvae. Wetting the crown and trunk with a contact or systemic

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organophosphorous insecticide has been applied in some cases. In areas the moth has recently entered, prompt destruction and burrying of infested trees, in conjunction with insecticides on neighboring trees has given hope of eradication. Eradication measures taken on Chios and Lesbos islands included the destruction of infested trees, covering with screen cloth host trees in nurseries, and frequent examination of host trees around the infested zones. In 2011 no new infestations were observed, suggesting that the measures taken were effective (Katsikogiannis et al. 2011). Injury has recently been recorded also to three palms of the species *Phoenix theophrasti* in central Crete (Niamouris and Psirofonia (2012). This suggests urgent eradication measures to protect the precious forest of *P. theophrasti* at Vai, southeastern Crete.

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