





DAMAGING POPLAR INSECTS

Internationally important species

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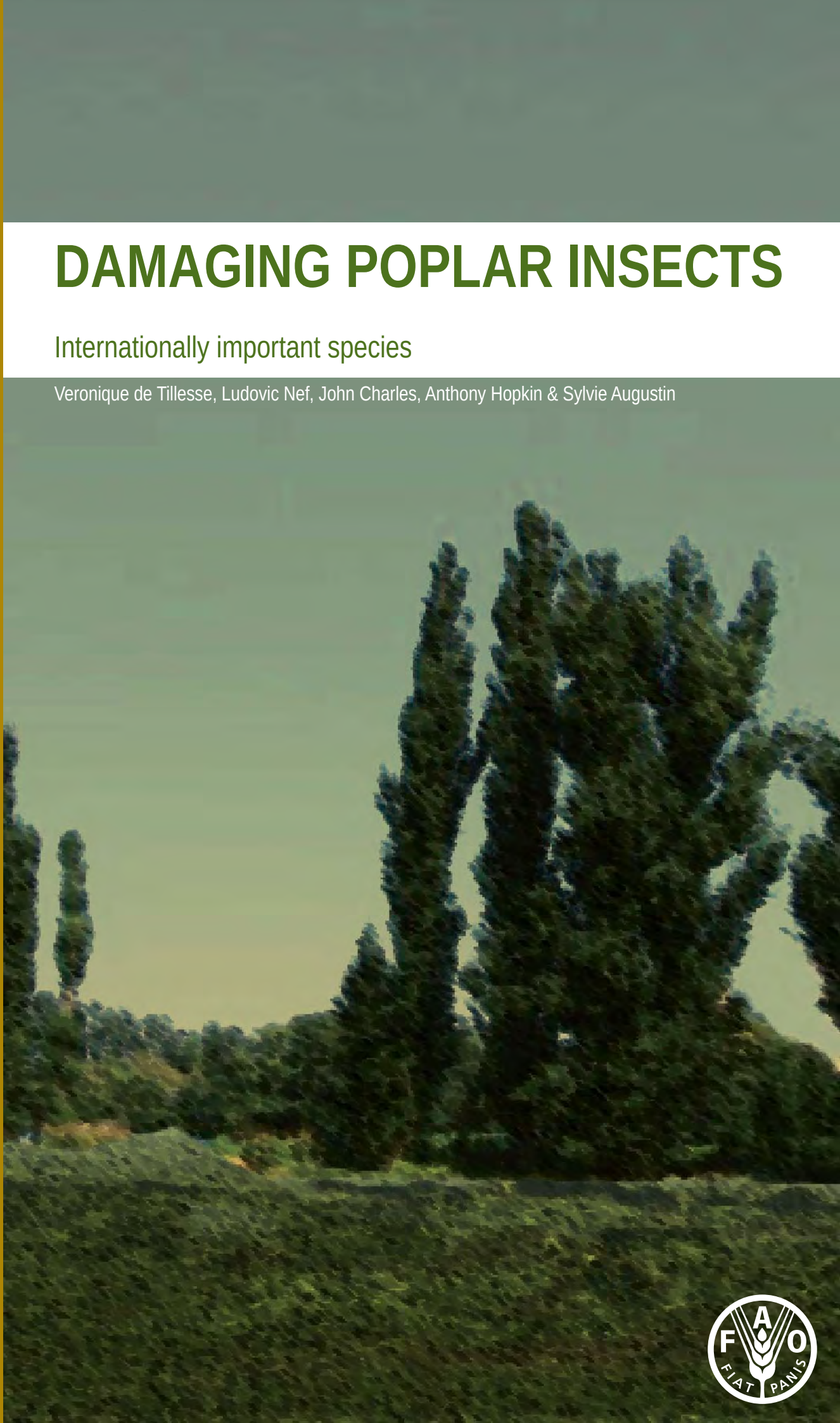

DAMAGING POPLAR INSECTS

Internationally important species

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1 - INTRODUCTION AND ACKNOWLEDGEMENTS

In 1956, the FAO published the book “Poplars and Willows in wood production and land use”, which brought together information on the genetics, improvement, growth and enemies, etc of these genera of major economic importance.. The introduction emphasised the role of Salicaceae in wood production, providing a renewable primary resource with a variety of uses. This publication led to outstanding collaboration between scientists and practical users from many countries, which resulted, *inter alia*, in the creation of the International Poplar Commission (IPC) in 1957.

Within this collaborative framework, scientists from various disciplines worked together to improve the quality and quantity of poplar production. It was in the spirit of this framework that the second completely redrafted version of the work “Poplars and Willows” was produced in 1980, for which most chapters were written by teams of specialists.

These books were very successful but, despite continuing demand, both eventually went out of print. Economic constraints prevented the production of further editions. With this in mind during the Budapest congress in 1996, the FAO and IPC management envisaged the preparation of booklets covering the same content, but to be published over a period of time, preferably as an Internet edition. Within this context, the chairman of the IPC Working Party on insects (L. Nef) was asked to draft a text on insect pests of international importance.

This request was fortunately preceded by a study of poplar, willow and alder pests (Morris, 1986); by a more recent publication aimed at providing a reasonably exhaustive list of the main poplar pests at an international level (Nef & Menu, 1994); and by the information contained in the national reports presented to the IPC congress in Budapest, and collected by the secretary of the insect working party (Augustin[1] 1996). This groundwork was extensively supplemented by a detailed check of the publications cited in the CD-ROM “Tree CD” (Forestry Abstracts) and by data obtained directly from working party members throughout the world, providing a solid foundation for the present work.

This wealth of information substantiates the assertion of the insect working party chairman (on the fiftieth anniversary of the IPC during the World Forest Congress in Antalia (1997)) that: “knowledge of the biology, distribution and damage caused by insects is sufficient for current practice. In the future, only information on large biogeographical variations, or of the appearance of new pests, will be of importance. The next problem is protection against damage. This will make use of integrated control where clonal resistance will constitute the primary protective measure. Today, scientists have already gathered extensive relevant data which can be applied by practical users.”

This last field of knowledge is a recent development, and, although it will always remain a step behind the progress of the breeders, it should be seen as useful, if not essential, to communicate progress to poplar growers: that is a major aim of this publication.

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The primary editors are especially pleased to thank all those who helped in preparing or improving this work. In addition to those who took part in the various studies referred to above, special acknowledgement is due to our colleagues who helped in the preparation and correction of this manuscript: J. Bain, J. Ball, D. Calderon, I. Chaudry, Eule Rae Noh, Y. Hifan; and to those who provided valuable and detailed contributions: G. Allegro, A. Delplanque, V. Steenackers.

The illustrations were provided especially by G. Allegro, S. Augustin, T. Cerillo, R. Coutin, R. Crabtree, A. Delplanque, Y. Han, A. Hopkin, The Canadian Forest Service, and L.Nef.

1 S. Augustin is currently chairman of the Insect working party.

2 - LIST OF TREATED SPECIES

Table 1 lists the scientific names of insects included in this study, alphabetically by genus within insect Order. It groups them in broad biogeographical Regions in order to clarify interpretation and use. Each Region (abbreviated column headings in Table 1) features information obtained from the following countries:

Explanation of geographical regions used in the tables and text.

HOLARCTIC		
East and West American region	Amer	Canada, United States
Euro-Siberian region, Atlantic domain	Atl	Belgium, Germany, Finland, France, Great Britain, the Netherlands
Euro-Siberian region, Mid-European domain	MEur	Austria, Bulgaria, Hungary, Romania
Mediterranean region	Medit	Egypt, Italy, the Maghreb, Portugal, Spain, Syria, Turkey, ex-Yugoslavia
Aralo-Caspian region	AraCp	Iran, Iraq, Pakistan
Chinese region	Chin	China, Japan, Korea
INDOMALESIAN	IndM	India
NEOTROPICAL	Neotr	Argentina
AUSTRALO-PAPUA	AusPp	New Zealand
AFRICAN	Afr	South Africa

Explanation of symbols

There are innumerable poplar pests; for example, A. Delplanque (1998) cites almost 500 species for Europe, and Hopkin some 750 for North America. This work only deals with pest insects of major international importance, and distinguishes three categories:

❍ = important species, but local or occasionally found
✣ = important species, occurring quite frequently
■ = frequently occurring and particularly harmful species

3 - CRITICAL COMMENTS ON THE LIST

The list obtained from the various sources mentioned above has some surprising features. For instance, Palearctic poplars seem to suffer far more from insect damage than those in the Nearctic, southern Asia or in Oceania. Perhaps one might be tempted to explain this by a greater awareness among entomologists in the Euro-Mediterranean or Chinese regions to insect damage. But, more seriously, an hypothesis proposed by the former IPC Chairman V. Steenackers, offers a biological basis to explain these differences: monoclonal plantations have become very widespread, especially in the former, and more recently in the Chinese region. In Western Europe these plantations were started approximately a hundred years ago, which has provided enough time for insect pest populations to proliferate. In North America and southern Asia, poplars are almost exclusively cultivated in semi-natural populations, and in South America and New Zealand monoclonal plantations have only been recently introduced.

If this hypothesis, which seems extremely realistic to us, is confirmed, it will necessitate strict application of the precautionary principle "*in dubio, abstine*". In the future, it will be essential to avoid monoclonal plantations and to revert to growing techniques that are closer to natural or semi-natural conditions. A first

step in this direction will be to increase the number of polyclonal plantations or to resort to small mosaics of monoclonal stands, after having found a solution to the problem of growth homogeneity and technological characteristics of clones. These artificial poplar stands, established according to the main pests and diseases in each area, must aim to recreate a new balance between the tree and its enemies - as is achieved in natural populations.

4. - TYPES OF DAMAGE AND ITS PHYSIOLOGICAL, ECOLOGICAL AND ECONOMIC IMPACTS

NOTE: Various insects mentioned in this chapter are not included in the systematic Chapter (§ 6), as their importance does not warrant it. But they may be representative examples of certain types of damage. Based on a non-exhaustive literature search, this chapter presents several examples that clearly illustrate the international nature of research.

4.1 - MAIN TYPES OF DAMAGE

Damage by **defoliators** is certainly the most spectacular, and large numbers may lead to total defoliation. Under more moderate attack, damage is partial. Damage can sometimes take distinctive forms, such as, for example, in the case of attacks by "leaf-rollers" (*Byctiscus* spp., phyllophagous leaf-rolling Coleoptera). Tenthredinid larvae often begin their attack from the edge of the leaf. The larvae of many Coleoptera destroy ("skeletonize") only one epidermis of the leaf, while the adults often cut fairly small window-type holes.

Damage by **leaf miners** is less spectacular. It is caused by Lepidoptera, Diptera, Hymenoptera, and more rarely Coleoptera, which form thin tunnels or tracks within the thickness of the leaf. These insects can sometimes be extremely numerous: in Belgian field trials, 75% of the leaves of certain clones were mined by *Phyllocnistis unipunctella* (Nef, 1988).

The **borers** or **wood borers** excavate galleries in the trunk or branches. The galleries of most trunk borers can be quite sizeable and are often sinuous; those made by shoot borers are smaller and very often straight.

Most **sucking insects**, such as aphids and cicadas, merely extract the sap from the tree. If the trunk is targeted, the tree often reacts by modifying the structure of the bark. Other sucking insects, such as certain aphids and Thysanoptera, feed on soft plant tissues.

The attacks of various borers such as *Gypsonoma* sp. or certain *Sesia* (= *Aegeria*) sp., or of sap suckers, lead to the formation of **galls** - tissue outgrowths on branches or leaves. Aphids, such as *Pemphigus* attacking leaf petioles or stalks, induce galls with a complex structure, for example like a "corkscrew" (*P. spirothecea*). *P. bursarius*, which is host specific to *Populus nigra*, is even used as an index of the genetic purity of poplars of this species within its natural distribution (Steenackers, pers. comm.).

4.2 - IMPACT OF DAMAGE

Defoliators, leaf miners and sap suckers especially induce **physiological** effects: tree growth slows down, or the tree can even die in the most serious cases. Some examples are:

(i) Artificial defoliation of 75%, imitating that of *Clostera* (=*Pygaera*) *anachoreta,* reduces tree growth by approximately 20%; defoliation of 100% reduces it by some 50% (Gao *et al*, 1985).

(ii) Attack by *Chrysomela scripta* reduces the growth of seriously defoliated clones by 80% (Caldbeck *et al*, 1978).

(iii) Attacks by *Phyllonorycter* (=*Lithocolletis populifoliella*) hasten leaf-fall, delay growth and diminish the aesthetic value of poplars (Belova *et al*., 1987).

(iv) Poplar growth is decreased by 17% if there is an average of 21 *Quadraspidiotus gigas* (an armoured scale insect) per $cm^{2,}$ and by 31% if there are 38 per cm^2 (Hu *et al*,1985).

(v) *Aphis maculatae* hardly affects the growth of various hybrids, despite major differences in degrees of attack (Wilson *et al*, 1986).

(vi) The surface area, and thus the photosynthesis, of leaves attacked by the leaf miner *Phyllocnistis unipunctella* is 25% smaller than that of undamaged leaves. Both mineral elements and polyphenols are modified. The latter, a defence response induced by the plant, reduces the number of insects and slows down the growth, weight and fecundity of the survivors (Nef, 1986).

Defoliation in spring, which allows the poplars to produce new foliage in the summer, will only slow down growth by a few percent. On the other hand, summer defoliation, particularly if repeated over several consecutive years, can reduce tree growth by half or even more, and can sometimes kill the tree.

Mechanical damage is mainly caused by borers. These insects weaken the trunk and, in particular, make them unsuitable for many uses, especially the most valuable (sawing, veneering). Even the tiny vertical galleries made by *Phytobia (=Dizygomiza*) in cambium can subsequently cause black lines or even cracks when veneering.

On the other hand, many trunk borers have hardly any measurable impact on paper or pulp production.

Despite their abundance, the galleries of *Sesia* (=*Aegeria*) *apiformis*, restricted to the lower parts of the trunk, cause hardly any damage to large poplars; but those made by *Cryptorhynchus lapathi* can kill an appreciable percentage of young trees (25% in the Netherlands) (Moraal, 1996).

Shoot borers, particularly harmful in nurseries, can cause stems to rot and, especially, to break. *Paranthrene* spp. or some *Compsidia* (= *Saperda*) spp. are regularly accused of this. *S. inornata* can attack up to 60% of shoots, but few are broken and ultimately these attacks have little impact on growth (Moore *et al,* 1986).

Death of the terminal shoot, which is frequently caused by *Gypsonoma aceriana*, will often result in forking of the stem, diminishing the commercial value of nursery trees.

Various insects can modify tree structure. *Phlœomyzus passerinii* causes cracks in the bark, wood necrosis and interupts sap circulation.

Insects can interact with **micro-organisms**. Or rather, the presence of the latter allows or facilitates insect attack. The graphic interaction of the elm - bark beetles is universally known. On poplars, *Platypus sulcatus* introduces *Ambrosia*. Another scenario is where the insect accidentally introduces the disease, which can sometimes be more harmful than the insect. There is a quantitative relationship between *Cryptorhynchus lapathi* and the canker *Mycosphaerella populorum* (Abebe *et al*, 1990); between the canker *Cytospora chrysosperma* and *Melanophila decastigma* (Liu *et al*, 1988); and between the tunnels made by Agromyzidae and *Xanthomonas (Aplanobacter*) *populi*, which causes bacterial canker (Steenackers, pers. comm.). Many bacteria are introduced when trunks are attacked by *Lygus lineolaris* (Juzwik *et al*, 1986). The bacterium *Erwinia salicis* can survive in the galleries of willow and probably also poplar insects (Steenackers, pers. comm.).

Damage can also be **ecological** and **aesthetic**. A pest outbreak can reduce, if not destroy, the shelter function of a windbreak. The use of poplars as windbreaks can sometimes prove to be ill-fated if they introduce undesirable pests into, for example, neighbouring apple crops (Tertyshnyi, 1991). Urban plantations lose their aesthetic value following attacks by the leaf miner *Zeugophora turneri,* which spoil the leaves and causes premature leaf-drop.

Often also, the attacks can have **multiple consequences**. The borer *Saperda calcarata* can facilitate the establishment of disease and other insects, and also makes the trunk vulnerable to breakage from wind or snow (Drouin *et al*, 1975). Various fungi, such as *Xanthomonas populi*, and borers such as *Cossus cossus* follow in the wake of attacks by *Paranthrene tabaniformis* (Bertucci, 1986).

5. - INTEGRATED PEST MANAGEMENT

Integrated control is a strategy using all available control methods with the aim of managing pest populations within acceptable levels. Every case should be considered based on local conditions, real pest density and actual or expected damage. Control decisions have to take into account economic, ecological and social factors.

Integrated control leads to ecological manipulation of insect populations and their environment, and thus requires thorough knowledge of pest ecology and associated organisms.

In this strategy, many possible measures are available. Several concern preventive action, which should be preferred wherever possible, and suppressive action. The latter, which often give only temporary protection, are sometimes unadvisable or even harmful from an ecological point of view, and are often more expensive; expenditure on young trees will only be recouped at felling, which presumes long-term investments and thus a much higher cost than the initial expenditure.

5.1 - PREVENTIVE METHODS

Cultural control is the primary control measure, and maybe the most important. Silviculture aims to adapt poplars to their optimal planting conditions, or to the most hostile conditions for the most harmful pests, and to create or maintain plant structures that deviate little from natural conditions.

Thus, the use of monoclonal plantations is probably a major cause of the proliferation of insect damage in the Euro-Mediterranean area and in China. It is thus urgent to promote the use of mixed plantations in line with criteria suggested in § 3.

Site and stand management play a considerable role in limiting damage. In many cases, soils favourable to poplar growth (good ventilation, good water provision and pH (pH (KCl) from 5.5 to 7), are unfavourable to insect attack. Moreover, trees subject to various physiological stresses (drought, unsuitable positioning, bad plantation techniques) resist less or can be even killed by attacks. A number of examples are quoted for the damage of defoliating caterpillars, *Agrilus ater* and other related borers: *Agrilus suvorovi, Capnodis miliaris, Melanophila picta, Poecilonota variolosa.* Furthermore in the case of *Gypsonoma aceriana,* attacks become rarer if cover is not very dense (Cavalcaselle, 1972; Sekendiz, 1973; Heymans, 1984; Solomon, 1993). Exploratory research showed that the intensity of defoliators' damage is correlated with various chemical elements in the soil, such as the C/N relationship and potassium, or iron and calcium (Hakizimana and Nef, 1998).

Poplar growth is satisfactory near industrial complexes that produce iron oxides or fluoride. But pest damage, especially by tetranychid mites and aphids, is definitely more abundant (Makhovskaya *et al*, 1984).

Damage by *Paranthrene tabaniformis*, and various other insects, is reduced by planting trees in areas not infested by these pests (or in an area with either few or resistant poplars), using fertilizers, by destroying young suckers, and controlling defoliators (Bertucci, 1986). However, repeated chemical control, especially with nonselective insecticides, may induce *P. tabaniformis* outbreaks (Giorcelli and Allegro, 1999). The removal of attacked trees is always a useful if not essential measure (e.g.: reduction of *Anoplophora nobilis* populations, Zhou *et al*, 1981). In the same way, the destruction of leaves makes it possible to remove leaf miners hibernating in the attacked leaves.

The use of wastewater does not increase borer attack, especially from *C. lapathi*, unless they are excessive or salted (Szontagh, 1981).

Comparative experiments showed that *Phyllocnistis unipunctella* was less abundant on sandy grounds than on muddy and wet grounds: it is assumed that these soils modify the chemical composition of the leaf (and especially that of tannins) and hence increase insect mortality (Nef 1982).

Trees in the centre of plantations, and those on rich soils, are more subject to attack by *C. lapathi* (Attard, 1978).

Leucoma salicis outbreaks are very rare in poplar plantations with an abundant and varied understorey: caterpillars migrate regularly from tree to tree, but, as poplars become scarcer, they are more likely to find themselves on trunks of undergrowth on which they cannot feed and risk starvation. Low plant diversity may be one reason why linear plantations, for example by the roadside, are more vulnerable to attacks by this insect.

In sunny and dry positions, broader tree spacing reduces attacks by *Phloeomyzus passerinii* (Arzone *et al*, 1984).

The introduction of various plants between the poplars can reduce damage from some pests. In nurseries, *Tagetes* reduce pathogenic nematodes. In the same way, *Erigeron canadensis*, a very attractive plant for *Lygus lineolaris*, can reduce its attacks on poplars by 90% (Sapio *et al*, 1982). The proximity of other plant species influences insect damage, either because they emit toxins, because they resist pests, or because they attract them in a specific way: the introduction of *Melia azedarach* and *Acer negundo* as tree-traps can reduce damage by *Anoplophora glabripennis* by 60 to 70% (Sun *et al*, 1990).

Genetic resistance constitutes the other major arm for poplar protection. The poplar grower should make wide use of knowledge available on cultivar or species resistance to insects. This resistance can come either from natural poplar characteristics, possibly improved by breeders, or those provided by biotechnology (for example by introducing genes that induce toxin formation for *Bacillus thuringiensis*). In either scenario, resistance should not originate from the action of a single gene but from the joint impact of a series of genes, thus ensuring wider and much more long-term resistance that pests will have great difficulty in circumventing.

Poplar and hybrid ecology influences their genetic defence mechanisms. For example, resistance strategies to *Phyllocnistis unipunctella* differ among hybrids originating from *P. trichocarpa* or from *P. deltoides,* which can be linked to the fact that the former is a forest species and the latter is a pioneer poplar (Nef, 1986). Indications such as these can guide the selector's work.

The objective is not to entirely eliminate the pest, which would mean exerting excessive selective pressure (insects also have their evolution mechanisms), but to bring pests back to acceptable levels for poplar growers.

Many polyclonal experiments carried out under varied planting combinations revealed that insect attacks on each clone are clearly linked to genetic factors as compared with poplars native to the area.

The advantages of this approach are no costs (after the preliminary research effort), wide specificity and good persistence. Research showed that the cultivar Robusta (*P. deltoides* X *nigra*), obtained approximately 100 years ago, is more susceptible to some insects than other *P. deltoides* X *nigra* crosses of more recent origin. This could provide a reason for continuing this control process. However this does not exclude the fact that there are also new clones which prove to be more sensitive than old ones towards certain insects. Generally, though, damage caused by defoliating caterpillars is about three times more abundant on *P. deltoides* X *nigra* hybrids than on *P. trichocarpa* or *P. trichocarpa* X *deltoides* clones (Nef, unpublished).

However, the research effort required to create or define resistant clones and then test them under various spacing conditions can often take up to 15 years of work.

As part of an integrated approach it is important to not rely on only one method. Many researchers have underlined interactions between plantation and clonal or specific susceptibilities: it is not unheard of that the most attacked poplars in one plantation can be the healthiest in another. It is thus essential to be well informed on this problem before choosing the cultivars or species for a given site. But this also demonstrates that there is no universal method for reducing insect damage. The only practical solution is to determine the most harmful insects in the area or site to be planted, and to choose the growing techniques and cultivars in line with this maximum risk.

5.2 - SUPPRESSIVE METHODS

Chemical control is the most widely known suppressive method. It is effective and easy to apply, but has many drawbacks; it encourages the formation of resistant strains of insects, decreases populations of their natural enemies, pollutes the environment considerably (including human foods), and erodes biodiversity. In fact, in a growing number of countries, insecticides are prohibited or can only be applied after receiving authorization. Treatment may have to be repeated. The use of pesticides with a short persistence only provides a slight advantage. On the other hand, targeted pesticides such as entomopathogenic micro-organisms might offer a more effective solution.

Microbiological control employs micro-organisms such as *Beauveria bassiana*, viruses, insect destroying nematodes or products from micro-organisms such as *Bacillus thuringiensis*. The next section provides various examples. In the field of silviculture, it is seldom necessary to obtain immediate mortality. Thus, the viruses of *Leucoma salicis* infecting larvae will have negative effects on each later development stage, up to the fertilization of the eggs in the next generation, and will destroy some 80% of the population over time (Nef, unpublished).

The application of entomopathogenic nematodes *Neoaplectana carpocapsae* associated with the bacterium *Xenorhabdus nematophilus* killed 90% of *Paranthrene robiniae*. The application is recommended from the very onset of the attack (Kaya *et al*, 1983). Using the same organisms, Cavalcaselle & Deseo (1984) obtained very positive results against *P. tabaniformis*, but less encouraging ones against *Cryptorrhynchus lapathi.*

As a precondition to any suppressive control, it would be advisable:

- to collate arguments based on its real necessity, and not just an impression of the pest impact. Estimates of expected damage should exceed a reasonable economic threshold. For example, the economic losses from defoliation by *Leucoma salicis*, greatly exceeds the cost of treatment using *Bacillus thuringiensis*).
- to choose the optimal treatment case by case;
- to apply the treatment in compliance with all the regulations relating to the period, the insect development stage and condition of the vegetation, dosage, and the places to be treated.

The decision will also depend on the types of growing environment: in plantations, even substantial damage can be tolerated if it does not kill the trees; but in nurseries, suppressive control will be more easily justified if the growth or shape of plants for commercial use is compromised by attacks.

Of course, national and state regulations for chemical control must be respected at all times.

5.3 - BIOLOGICAL CONTROL AND OTHER METHODS

Natural insect enemies are another weapon in integrated control. Augmentative or mass releases of parasites or predators are not very common in poplar growing because the spatial-temporal distribution of pests is too irregular to justify natural enemy rearing programmes.

Extensive plant biodiversity will encourage their natural populations, as well as those of other insect eaters such as woodpeckers (Picidae). These are great destroyers of various xylophagous insects, especially in winter. Their assistance thus largely compensates for damage caused by their nesting (Allegro, 1993).

Installing rings of lime around the base of trees or terminal shoots can prevent attacks from insects such as those that hibernate on the trunks (e.g. *G. aceriana*) or in the soil.

Mass trapping of *Paranthrene tabaniformis* to restrict populations can only be achieved in isolated plantations; otherwise, this method can only be employed as a monitoring method (Wu *et al*, 1987; Moraal *et al*, 1993).

5.4 - CONCERNING INTERCONTINENTAL EXCHANGES OF PLANT MATERIAL

In the past, intercontinental exchanges of plant material sometimes inadvertently spread diseases. Thus today it would appear more urgent than ever to regulate such exchanges.

A - Plant material

Regarding the risks of insect exchanges, various types of plant materials need to be considered.

There do not appear to be any important insect pests living in poplar seeds that can be transmitted. More insects can be found in the fruit structures, but fruits are never exchanged and there is little impact on seed viability. However, extreme caution should still be exercised in the movement of plant material. *Megastigmus spermotrophus,* a rather inoffensive insect that damages Douglas Fir seeds in North America, has become a major scourge in Europe, capable of destroying 90% of seeds. A repeat of such a misadventure should be avoided completely.

The movement of cuttings and seedlings is more problematic. In particular, the exchange of cuttings can lead to the transport of sap suckers and stem borers.

During exchanges of bark or other cut wood, many insects can be transported in a dormant stage (such as eggs or caterpillars hibernating in bark cavities) or in an active stage, for example on shoots. They may, in particular, be conveyed internally, where they are practically undetectable. There have been disastrous precedents, such as *Monochamus* association, nematodes and mushrooms that were introduced accidentally on conifers in Japan, or *Sirex noctilio* in Australia and New Zealand. In both cases, substantial damage resulted.

B - Basic precautions

Seeds should be subject to very detailed visual and radiographic examination in order to ensure they are not carrying any insect. Any exchange should be accompanied, both before and after dispatch, by pesticide treatment.

For small quantities of cuttings, thorough inspection should enable any insect to be detected and destroyed. Such inspections should be obligatory. As a precaution, heat and chemical disinfestation treatments (such as fumigation with hydrogen phosphide or immersion for several hours in a suspension of insecticide and

fungicide), should be carried out both before and after transport. For large-scale shipments, application of such measures would be impractical, discouraging or preventing such exchanges. The shoots that grow on cuttings, liable to transport defoliators and leaf miners, should be destroyed before and after transport.

At present, *in vitro* growing techniques offer the best possible solutions to the exchanges of new material. By definition, this material is free from bacterial infection and enables new plants to be produced rapidly and in great number. While this method will destroy insects, bacteria can sometimes avoid disinfection and viral disease presents an even greater risk.

The precaution of destroying shoots also applies to bark. But as for the other insects sheltered in bark, especially xylophagous ones, destruction seems difficult, if not impossible. Their export should thus be authorized only within the biogeographic limits quoted below. Preliminary debarking would probably reduce the risks, but can increase the risk of wood drying.

C - Biogeographic strategy

If plant material is transported for example from temperate to tropical areas, the development of associated insects will be impeded in this new environment; this applies to industrial bark exported to areas that are too hot for poplar growing. In such situations, possible precautionary measures may, in fact, turn out to be superfluous.

On the other hand, if material is transferred within similar biogeographic ecological zones, for example with the same climate, extreme precaution should be exercised: the inadvertent introduction of undesired species is also possible. It is possible to envisage two situations in these cases, as:
- either the distance is short and there are the same insect species in the two areas. In this case, imports present no problem, except where there are cryptic ecotypes with different invasive characteristics.
- or the distance is greater, which is usually the case in intercontinental exchanges. Here, extreme precaution must be taken to avoid tranfers. The measures or prohibitions suggested above should be applied thoroughly.

On the whole, the geographical risk of extending insect populations is considerable, even when serious precautions are taken.

The above-mentioned precautionary measures seem essential to a general poplar protection strategy. As a prerequisite, they require thorough knowledge of potentially damaging insects at both the starting and arrival points of any exchange. Exchanges should only be allowed if the pest is present in the two areas, or if the distance between the zones does not exceed that which the insect could cross under normal biological conditions.

But it should not be overlooked that diseases and animals also have their own expansion strategies, which have been enhanced by human mobility. It is thus rather utopian to hope to limit a pest's final distribution, unless biological conditions make it impossible.

And finally, it is necessary to establish strict regulations governing such exchanges (based for example on European Union directives), to define monitoring techniques and the skills and responsibilities of those who will be in charge, to set possible sanctions, and to set up the necessary structures, such as laboratories to check the health conditions of material and to update the lists of potentially damaging species.

5.5 - SOME CONCLUSIONS

Integrated control of poplar insects will apply many non-chemical tactics and will only employ chemical measures in extreme circumstances, or more likely, in nursery conditions.

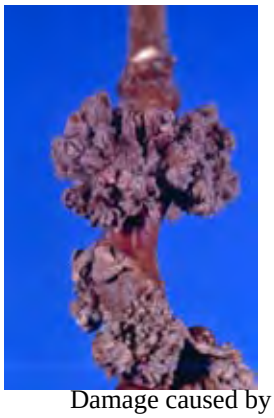
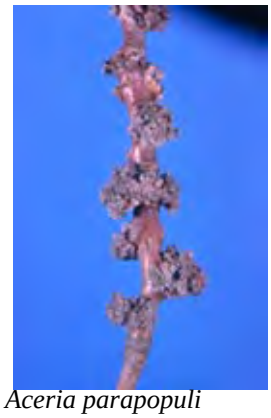
These control techniques should be adapted to the most damaging insects in the region concerned. Particular recommendations include: optimization of plantation conditions; appropriate silviculture; adoption of mixed plantations; selection of resistant species or cultivars; use of suitable under-storey vegetation; and extreme caution in intercontinental exchanges of plant material.

6 - SYSTEMATIC SURVEY

This chapter presents species in alphabetical order, for easy reference by the reader. Photographs illustrating the insects or their damage can be magnified by clicking on the photo or icon. Closing the enlargement will return to the text or other pictures.

Table 1 in chapter 2 provides a systematic and biogeographic classification of the pests discussed.
Table 2 summarises the various types of damage caused by these insects.

Aceria parapopuli (Keifer) (Acarina, Eriophyidae)

Damage caused by *Aceria parapopuli*

Origin and Global Distribution: *Aceria parapopuli* is found in North America, including Canada.
Description: A very small, whitish coloured mite about 0.2 mm long, with 2 pairs of legs. It is not visible to the naked eye.
Damage: This eriophyid mite causes bud distortion and prevents natural development. Damage to young poplars can be considerable.
Biology/life-cycle: The immature stages and adults feed on the buds of *Populus* spp.
Control: Control is difficult because mites spend most of their time inside the galls. Infestation can be reduced by pruning and burning all the branches with galls. In nurseries and young plantation, chemical control can be implemented.

Altica (=*Haltica*) *populi* Brown (Coleoptera, Chrysomelidae)

Altica populi adult

Altica populi larvae feeding on leaf

Origin and Global Distribution: *Altica populi* is found in North America.
Description: A greenish-blue chrysomelid, 4-5mm long, with posterior hind leggs adaptated for jumping. Larvae are rather elongate, white-yellowish with 6 legs and a dark head.
Damage: Larvae and adults are leaf skeletonisers. This leaf beetle is usually not regarded as a severe pest but it can occasionally cause serious defoliation.
Biology/life-cycle: Feeds on *P. tacamahaca* and *P. tremuloides*.
Control: In heavily infested area, contact insecticide can be applied.

Anaerea spp. (Coleoptera, Cerambycidae)
Anaerea (=Saperda) carcharias (Linnaeus)
Anaerea (=Saperda) calcarata Say


Anaerea carcharias adult on leaf

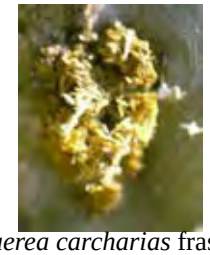

Anaerea carcharias larva in gallery


Anaerea carcharias pupa in gallery


Anaerea carcharias injury in the wood


Anaerea calcarata adult


Anaerea calcarata larva in gallery


Anaerea carcharias frass on the trunk

Origin and Global Distribution: *Anaerea carcharias* is a very common species over the whole of Europe and part of Asia. Another species, *A. calcarata*, has the same life-cycle and is widely distributed in North America.

Description: *A. carcharias* is a large insect with a black tegument covered with a yellowish/greyish pubescence. It is 20 to 30 mm long.

Damage: *A. carcharias* is regarded as the main poplar pest in the Mediterranean basin. The adults feed on leaves, making more or less elongated perforations that do not reach the edges. They also feed on the bark of new growth, causing bark necrosis and branch dieback. Larval damage is much more serious. They bore an initial, horizontal peripheral tunnel just underneath the bark, which causes swelling and gall formation. Subsequently they penetrate more deeply, seriously damaging the wood, which is then rendered unsuitable for many uses, and allowing the invasion of microorganisms.

Biology/life-cycle: The life-cycle lasts 2 to 4 years, according to climatic conditions. The adults emerge in the middle of the summer, and mate and egg laying occurs from July to September. The females make an incision in the bark of poplars - preferably aged 5 to 10 years old. They usually lays her eggs in the lower part of the trunk of young trees. On older trees, eggs may be laid on any part of the tree. The larva hatches only in May or June of the following year and bores a horizontal tunnel towards the centre of the tree. The larval galleries of this large wood borer are very long; some descend from the trunk to the roots then rise again to the centre of the sapwood. After heavy summer feeding, the larva hibernates and does not feed again until the spring of the following year. It pupates at the beginning of summer, and about a fortnight later the young adult emerges from the larval gallery.

Control: One can try to control these borers by coating birdlime (a sticky barrier) on the lower part of the trunk to prevent oviposition. Woodpeckers (especially the Great spotted woodpecker in Europe) eat many larvae. Attempts should be made to encourage their nesting near poplar plantations. Chemical treatments can be employed effectively when larvae are present on the bark (just after hatching). In young poplar plantations, most eggs are laid at the base of plants. Insecticides could be injected into the larval holes, which could then be resealed. But there is no completely effective process; the attacked poplars should be felled to avoid infestation of healthy trees nearby.

Anoplophora spp. (Coleoptera, Cerambycidae)
Anoplophora nobilis Ganglbauer
Anoplophora glabripennis Motchulsky
Anoplophora malasiaca (Thomson)
Anoplophora (=Batocera) horsfieldi (Hope)

Anoplophora glabripennis adult female

Anoplophora glabripennis larva in gallery

Anoplophora glabripennis pupa in gallery

Anoplophora glabripennis egg niches and sap streak on trunk

Anoplophora glabripennis injury in trunk

Anoplophora horsfieldi adult

Anoplophora glabripennis adult

Origin and Global Distribution: *Anoplophora nobilis* and *A. glabripennis* are found in China and N. America; *A. malasiaca* in Japan. *A. horsfieldi* is found especially in China but also in the north of India and Pakistan.

Description: Adults are blackish longicorn beetles, with lines of small, whitish punctuations on the elytra. Larvae are slightly coloured a white-yelowish with a dark brown head.

Damage: *A. nobilis* and *A. glabripennis* cause considerable economic damage, especially in China, where *A. glabripennis* has become the most important pest insect and the most difficult to control. *A. glabripennis* has been accidentally introduced into N. America, establishing in New York and New Jersey in 1996, Chicago in 1998, Toronto in 2002, and into Europe, observed in Austria in 2001, in France in 2003 and in Germany in 2004. *A. malasiaca* is common in Japan and is just as damaging. The genera *Populus* and *Salix* are quite resistant to *A. glabripennis*: they continue to live, even if they have been continuously infested for ten years, and hence act as reservoirs of the beetle. It is impossible to remove all of the damaged trees. In China, certain poplars (*P. deltoides*: Lux, L 55/65; *P. tomentosa*; *P.* X *euramericana* cv. Dorskamp, San Martino; *P. alba* cv. Pyramidalis) are more resistant to *A. glabripennis* than others.

Biology/life-cycle: *Anoplophora* spp. feed by boring tunnels in more than 100 species and varieties of trees. The larvae tunnel in the upper part of trees. There is generally only one generation a year. Adults emerge between June and July according to climatic conditions and region.

Control: *A. glabripennis* is very difficult to control. Adults can be killed using pesticides. In plantations, they can also be attracted onto tree traps. Destruction of the larvae is difficult. For isolated trees or very small surface areas, it is possible to inject insecticides or spores of *Beauveria bassiana* into the insects' tunnel openings, which are clearly visible on the tree. In China the planting of relatively resistant hybrids is now preferred. In USA and Europe control measures aim to contain and eradicate the outbreaks.

Apriona spp. (Coleoptera, Cerambycidae)
Apriona cinerea Chevrolat
Apriona germari (Hope)
Apriona japonica Thomson


Apriona germari adult


Apriona germari larva


Apriona germari pupa


Apriona germari gallery in bark

Origin and Global Distribution: *Apriona cinerea* is found especially in the north of India and Pakistan; *A. germari* is a very harmful beetle in China and in Pakistan; and *A. japonica* is particularly active in Japan.
Description: The adult long horned beetles are approximately 25 mm long and greyish in colour.
Damage: The damaged poplar seldom dies, but is weakened and wind-blown branches easily break.
Biology/life-cycle: *Apriona* spp. are longhorn beetles that feed mainly on poplars. Adults feed on the tender bark of young branches, and lay eggs at the end of the summer, individually in cavities bored into live branches. After hatching, the larvae bore vertical galleries (two to three metres long), and can even reach the roots of young trees. The life-cycle of *A. cinerea* extends over three years, approximately a year and a half of which is for larval development. This species prefers 9 to 15-year-old *P.* X *euramericana*.
Control: Measures include the spraying of insecticides, trap trees combined with insecticides treatments or the use of insect-pathogenic organisms.

Batocera lineolata Chevrolat (Coleoptera, Cerambycidae)


Batocera lineolata adult on a leaf


Batocera lineolata adult


Batocera lineolata adult on bark

Origin and Global Distribution: *Batocera lineolata* is found in Japan.
Description: Adults are quite similar to *Anoplophora*, but the spots on the elytra are less regular. Larvae are similar to *Anoplophora* spp.
Damage: Trees are generally not killed by *Batocera* spp. but are seriously damaged. *Batocera lineolata* causes great damage in Japan.
Biology/life-cycle: Adults emerge from the end of May to the beginning of June and live approximately 4 months, feeding on bark of new-season's growth. The eggs are laid individually, generally at the base of the trunk underneath the bark. The larvae bore wide galleries about 20 cm long, in mature trunks at least 15 cm in diameter.
Control: These beetles can be controlled effectively by *Beauveria bassiana* and *Metarhizium anisopliae*.

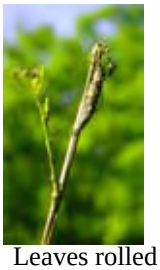
Byctiscus spp. (Coleoptera, Curculionidae)
Byctiscus populi (Linnaeus)
Byctiscus betulae (Linnaeus)


Byctiscus populi feeding on leaf


Byctiscus populi on rolled leaf


Leaves rolled by *Byctiscus populi*


Byctiscus betulae feeding on leaf


Leaves rolled by *Byctiscus betulae*

Origin and Global Distribution: *Byctiscus populi* is relatively common throughout Europe.
Description: *B. populi* is a 2 to 4 mm long and *B. betulae* is 4 to 7 mm long. Both are blue or metallic green beetles but *B. populi* is bicolor.
Damage: Both *B. populi* and *B. betulae* are polyphagous. Adults and larvae feed on poplar leaves. They show a clear preference for the clones of *P. deltoides* and euramerican hybrids. *B. betulae* may cause appreciable damage to poplars and willows.
Biology/life-cycle: A fertilised *B. populi* female "rolls" one poplar or willow leaf in which she lays her eggs while the *B. betulae* female "rolls" severall leaves. The larvae hatch 6-12 days after laying, feed on leaves and burrow into the ground to pupate. Adults emerge during August. They begin to feed again on leaves in the vicinity of the "rolls" then very quickly enter into diapause until the April of the following year.
Control: In general, the damage caused by these insects is limited and hardly requires control. In the rare cases of very damaging attacks, chemical treatment can be applied. To restrict dispersal of the weevils, the fallen rolled-up leaves should be collected and burned. Weevil proliferation is clearly encouraged by short or very short rotation plantations.

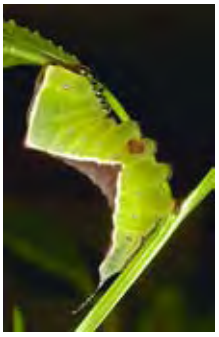
Capnodis miliaris (Klug) (Coleoptera, Buprestidae)


Capnodis miliaris adult

Origin and Global Distribution: *Capnodis miliaris* is found predominantly in Syria, Turkey, Iran and Iraq, but is also reported from the south of Italy.
Description: This is a large (30-40mm long) black, wood boring beetle, covered by a whitish deposit.
Damage: *C. miliaris* principally attacks water-stressed trees, and prefers plantations suffering from drought. A well-irrigated plot, even if located at the centre of an area that has been heavily attacked by *C. miliaris*, will hardly be attacked. Egg mortality on wet ground is very considerable.
Biology/life-cycle: Females oviposit at the foot of host trees from July to August. The larvae hatch after 10-15days, penetrate the base of the poplars and willows and feed between the bark and the wood, most often at the base of the tree and in the principal roots. The larvae overwinter between the trunk and the bark. The young adults appear between June and July of the following year to feed on leaves and young shoots, then spend the winter in the ground. There is only one generation every two years.
Control: The most effective control method is to establish plantations on properly irrigated ground.

Cerura (=Dicranura) spp. (Lepidoptera, Notodontidae)
Cerura (=Dicranura) vinula (Linnaeus)
Cerura (=Dicranura) menciana Moore


Cerura vinula adult


Cerura vinula larva


Cerura vinula cocoon

Origin and Global Distribution: *Cerura vinula* is present throughout continental Europe, including the United Kingdom. The closely related *C. menciana* is found in China.
Description: This robust moth has a wingspan of approximately 6 to 8 cm. The front wings are pale grey and crossed with dark zigzag lines. The back wings are pale-coloured. The body is stout and hairy. The defoliating caterpillar is characteristic: it is green with a large hump in the thoracic region, a saddle-shaped patch on the dorsum, and an anal extremity which ends in v-shaped appendices that can elongate when the caterpillar assumes a defence posture.
Damage: The damage caused by this insect is of little importance except in the event of an outbreak. Trees of all ages can be infested and significant defoliation can lead to reduced health.
Biology/life-cycle: The life-cycle lasts one year. Adults emerge between May and June. The eggs are laid on the lower face of willow or poplar leaves. The caterpillars feed on these trees until July or the beginning of September depending on climatic conditions. The pupal stage occurs within very elongated cocoons made up of a mixture of silk and bark fragments attached to the trunks of the host trees.
Control: This insect can be controlled using *Trichogramma*.

Choristoneura conflictana (Walker) (Lepidoptera, Tortricidae)


Choristoneura conflictana adult


Choristoneura conflictana larva


Choristoneura conflictana damage

Origin and Global Distribution: *Choristoneura conflictana* has a very broad distribution range. It is found in Canada from Labrador to Alaska, and it is equally encountered in the northeastern and central United States.
Description: The adult is pale grey with a wingspan of 20 to 30 mm.
Damage: It is an important pest of *Populus tremuloides*, but it also feeds on *P. deltoides* and *P. grandidentata*. Population outbreaks can lead to severe defoliation and often death of the tree.
Biology/life-cycle: There is only one generation a year. Eggs are laid in groups on the host leaves in the middle of the summer. The larvae hatch 7 to 10 days afterwards and feed gregariously between leaves held together with silken thread. At the end of August, the caterpillars descend to the tree base where they hibernate. They crawl back up the tree in spring and bore into the buds where they feed on the developing young leaves. The final larval stage rolls itself up in a leaf, and eats the tissue, leaving only the veins.
Control: Chemical control can be implemented.

Chrysomela spp. (Coleoptera, Chrysomelidae)
Chrysomela (= _Melasoma_) _populi_ Linnaeus
Chrysomela (= _Melasoma_) _tremulae_ Fabricius
Chrysomela (= _Melasoma_) _scripta_ Fabricius
Chrysomela (= _Melasoma_) _vigintipunctata_ Fabricius
Chrysomela crotchi Brown


Chrysomela populi adult


Chrysomela populi eggs


Chrysomela populi larva


Chrysomela populi pupa


Chrysomela populi and C. tremulae adults damage on leaves


Chrysomela tremulae adult


Chrysomela tremulae eggs


Chrysomela tremulae larvae


Chrysomela tremulae pupa


Chrysomela populi and C. tremulae larvae damage on shoots


Chrysomela scripta adult


Chrysomela scripta eggs


Chrysomela scripta young larvae


Chrysomela scripta larva damage


Chrysomela scripta adult damage

Origin and Global Distribution: *Chrysomela populi* and *C. tremulae* are found throughout Europe, but *C. tremulae* is particularly widespread in Hungary, Bulgaria and France. *C. vigintipunctata* is reported especially from Hungary, and *C. crotchi* is widespread in North America, including Canada.
Description: *C. populi* and *C. tremulae* adults are 6-12 mm long, with a metallic-red sheen. *C. scripta* and *C. vigintipunctata* are about 7 mm long, overall yellow to brownish-green in body color, and marked with black spots on the head and thorax, and broad black stripes on the elytra.
Damage: The most threatening leaf-feeding beetles in young poplar plantations and nurseries are *C. populi* and *C. tremulae*. In descending order, the preferences of *C. populi* and *C. tremulae* are: *Populus tremula* X *P. tremuloides* > *P. tremula* X *P. alba* [*P. canescens*] > *P. alba*. The latter is avoided, especially by *C. tremulae*. Both species prefer clones with smooth leaves. *C. vigitipunctata* feeds primarily on *Salix* spp., while *C. crotchi* mainly attacks *P. tremuloides* but can also infest *P. grandidentata*. Attacks of these beetles cause reductions in biomass or the death of young nursery plants, and destroy the new growth on old trees (which themselves are not as prone to attack).
Biology/life-cycle: These species have similar life cycles. Adults overwinter under dead leaves or in the soil and appear in April. The fertilized female generally lays groups of 15 to 65 eggs on the lower surface of the leaf. The larvae hatch 4 to 30 days later and pupation occurs a month to a month and a half afterwards. Depending on conditions, there can be 2 to 3 generations a year.
Control: Nursery infestation can be reduced by removing leaf litter around young trees, depriving the adults of their overwintering habitat, although certain leaf beetles hibernate in the soil. The other control method is to select sites with high humidity levels. Some insecticides can be applied successfully when the eggs begin to hatch.

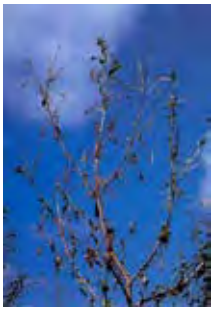
Clostera spp. (Lepidoptera, Notodontidae)
Clostera (=*Pygaera*) *anastomosis* Linnaeus
Clostera (=*Pygaera*) *anachoreta* (Denis & Schiffermüller)
Clostera (=*Pygaera*) *cupreata* Butler
Clostera (=*Pygaera*) *fulgurita* Walker

Clostera anastomosis adult on a leaf

Clostera anastomosis larva

Clostera anastomosis defoliation

Clostera anachoreta adult on a leaf



Clostera anachoreta larvae on a leaf

Clostera anachoreta defoliation

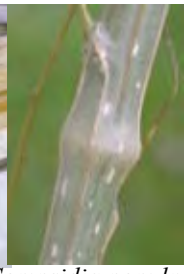
Origin and Global Distribution: *Clostera anastomosis* is found in Europe, Siberia and in Japan; *C. anachoreta* in Korea, Japan, China, India and in Pakistan; while *C. cupreata* and *C. fulgurita* can cause important defoliation to poplars and willows in the north of India and in Pakistan.
Description: They are squat nocturnal moths.
Damage: Species in the genus *Clostera* develop mainly at the expense of poplars. They can cause considerable devastation in poplar and willow plantations. *C. anastomosis* feeds especially on *P. tremula*, but *P. euramericana, P. euphratica* and *P. nigra* are also vulnerable.
Biology/life-cycle: *C. anastomosis* has only one generation in Siberia, from one to four annual generations in Europe and as many as nine in Pakistan. These Notodontidae are extremely prolific, due to the considerable number of eggs laid by each female (from 400 to 800) and to the high number of generations each year.
Control: In India, *C. cupreata* is controlled effectively with *Trichogramma*. Traditional insecticides also give good results but, because of the fecundity of the moths, they must be applied frequently.

Compsidia (=*Saperda) populnea* (Linnaeus) (Coleoptera, Cerambycidae)

Compsidia populnea adult

Compsidia populnea egg in horseshoe shaped notches

Compsidia populnea larva in gallery



Compsidia populnea gall on branch

Origin and Global Distribution: This species is widespread all over Europe, the Middle-East and in the rest of Asia and in northern America.

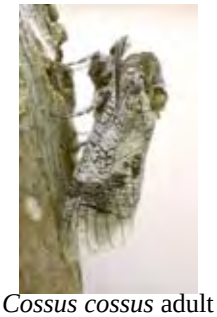
Description: These long horned beetles are smaller and more elongated than *Anaerea carcharias*. The beetle is approximately 14 mm long and is grey-black with faint spots of yellowish pubescence on the elytron.

Damage: Adult damage is negligible. They cut holes in the leaves similar to those of *A. carcharias*. By contrast, the larvae are much more dangerous in young plantations and nurseries: the side branches are often deformed, or, when they tunnel into tree tips, they cause them to break easily at the level of the galling when exposed to wind. For older trees planted under good conditions, it is an insect of secondary importance. If the tree is vigorous, there is virtually 100% egg mortality.

Biology/life-cycle: The life-cycle lasts one year in temperate areas but two to three years in colder regions. The adults emerge in spring and feed on the foliage and the tender bark of poplars and willows. Extended oviposition occurs from the beginning of May until July. The eggs are laid in horseshoe shaped notches carved out by the females, preferably on small, lignified branches from the previous year. The larvae hatch after 10-15 days. The young larva bores a circular gallery under the bark, causing a characteristic bulge at the base of the branch. It subsequently penetrates the wood and then the heartwood, which it follows upwards. The larvae hibernate from October-November and emerge the following year, or spend another one or two years as larvae while continuing to tunnel.

Control: The best way to avoid damage by *C. populnea* is to plant poplars that are perfectly adapted to environmental conditions and to avoid planting close to aspen poplars, which are an important source of infestation.

Cossus cossus Linnaeus (Lepidoptera, Cossidae)



Cossus cossus adult

Cossus cossus larva

Cossus cossus pupal exuvia

Cossus cossus damage at the base of the trunk

Origin and Global Distribution: *Cossus cossus* (the Goat moth) is very common in Europe and North Africa.
Description: It is a large grey-brown moth with a wingspan of 5 to 7 cm (male) or 7 to 9 cm (female). The caterpillar, which can reach 10 cm in length, is reddish-brown above and yellowish on the underside. The head is black.
Damage: This species is extremely polyphagous, attacking fruit trees as well as a large number of forest species such as *Quercus, Acer, Alnus, Salix, Populus* etc.
Biology/life-cycle: The life-cycle varies from two to four years depending on climatic conditions. The eggs are laid in groups of 15 to 30 in bark cavities close to the base of the trunk or in tree wounds. The caterpillars hatch in about a month. They feed initially on bark and then bore large branching tunnels, several centimetres wide, into the wood. After two or three winters, they pupate in the same tunnels, or in the ground in sheltered locations. The adults emerge in June or July and are crepuscular.
Control: These insects cause considerable damage because the larvae are very voracious and are often very numerous on a single tree. The most affected trees are old, or have wounds or cankers. It is possible to treat recently hatched larvae with contact insecticides. Later, it is necessary to resort to injections into the tunnels, taking care to penetrate through the frass blocking the entrance. Badly damaged trees should be felled and destroyed.

Cryptorhynchus lapathi (Linnaeus) (Coleoptera, Curculionidae)

Cryptorhynchus lapathi adult

Cryptorhynchus lapathi larva

Cryptorhynchus lapathi damage on young branch

Cryptorhynchus lapathi sap streak

Windthrown poplar after *Cryptorhynchus lapathi* attack

Origin and Global Distribution: *Cryptorhynchus lapathi* is widespread throughout Europe, China, Japan, the United States and Canada.
Description: *C. lapathi* is a grey-black, 9mm long weevil. The elytra have distally white or yellow patches.
Damage: This species attacks Salicaceae. *Alnus* and *Betula* are occasional hosts. The seriousness of the damage depends on the size of the plant host. Larval galleries can completely ring-bark young trees and kill them. More often, the galleries weaken the trees, which break easily in a strong wind. Damage can be seen from the exterior of the tree by the swelling of attacked young branches, by the small piles of frass and sap on the bark, and by a very characteristic “coffee bean” shaped scar. On poplars, major damage is caused only by larvae; on willows, larvae and the adults cause significant economic damage. During feeding, the adults cause small branches to break thus making them unusable for basket making. It has been noted that trees in

the centre of plantations and those on rich soils are the most vulnerable to attack.
Biology/life-cycle: *C. lapathi* has a life cycle of one or two years depending on climatic conditions: one year in Asia and southern Europe, two years in northern Europe and colder countries such as Canada or the United States. Having left the puparium in July, the young adults feed on bark and young branches and then overwinter in the ground. In the following spring, oviposition takes place at five to six metres above ground in holes drilled by the female, most often close to the buds. Once hatched, the larvae bore short, more or less horizontal galleries in the wood. In the final phase of its development, the larva penetrates more deeply by boring horizontal, slightly ascending galleries. The larvae either complete their development the same year, or they spend another winter as larvae before pupating.
Control: To restrict damage to poplar, any birches, alders and especially willows growing in surrounding areas must be removed. Willows provide good sources of contamination. *C. lapathi* females are attracted more to rough-barked poplars for egg-laying than smooth-barked varieties. The hybrids *P.* X *euramericana* cv. I 45/51 are the most heavily attacked. Chemical treatments are only effective as the adults hatch and attack the young branches, or just before oviposition. In Italy, the insect is controlled by trunk applications of insecticides when the larvae have just hatched.

Dasineura (=*Rhabdophaga*) *salicis* (Schrank) (Diptera, Cecidomyiidae)

Dasineura salicis gall on willow branch

Origin and Global Distribution: This is a common insect all over Europe, and has been introduced to North America.
Description: The adult is a tiny fly, active in May. Mature larvae are about 5mm long, initially whitish, but then yellow-reddish.
Damage: Branches can no longer be used in basket making.
Biology/life-cycle: The eggs are laid on the young branches of several species of *Salix,* including *S. cinerea* and *S. purpurea*. The larvae feed gregariously causing long irregular galls in which they live in separate chambers. Pupation takes place in the gall and the adults emerge in spring.
Control: The best control is to plant less vulnerable cultivars.

Epinotia solandriana (Linnaeus) (Lepidoptera, Tortricidae)

Epinotia solandriana adults

Epinotia solandriana larva

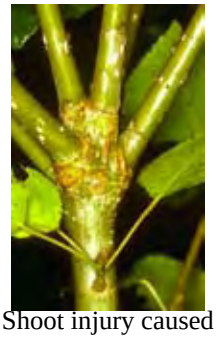
Origin and Global Distribution: *Epinotia solandriana* is common in Europe and North America.
Description: This is a small moth.
Damage: In Europe, *E solandriana* does not appear to cause much damage, but in Canada it causes serious defoliation of *Populus tremuloides*.
Biology/life-cycle: The larvae mainly infest the foliage of *Populus* spp. but are also common on *Betula*. They roll leaves up into cigar shapes.
Control: In general, the damage caused by these insects is limited, but in the rare case of severe attack, homologated insecticides can be applied.

Gypsonoma spp. (Lepidoptera, Tortricidae)
Gypsonoma aceriana (Duponchel)
Gypsonoma haimbachiana (Kearfott)

Gypsonoma aceriana adult

Frass of Gypsonoma aceriana young larva

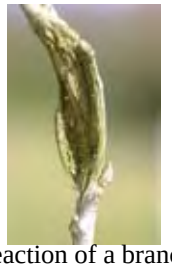
Frass of *Gypsonoma aceriana* larva on young shoot



Shoot injury caused by *Gypsonoma aceriana*

Gypsonoma haimbachiana larva

Repeated attacks of *Gypsonoma aceriana*



Reaction of a branch after attack by *Gypsonoma aceriana*

Origin and Global Distribution: *Gypsonoma aceriana* is widespread all over Europe and in North Africa. *G. haimbachiana* is found in North America, and *G. riparia* is common in Pakistan.
Description: These are small light-coloured moths (12 to 14 mm) with brown stained tips on the front wings. The caterpillar is 8 to 12 mm in length, almost hairless, and a yellowish colour with a brown head.
Damage: *G. haimbachiana* attacks young plantations of *Populus deltoides*. The larvae of *G. riparia* skeletonise leaves of *Populus euphratica* and web them together into a tight net. The damage to adult poplars is negligible but damage can be much more serious in nurseries or young plantation, especially when the apical buds have been attacked. The dominant terminal shoot is then replaced by a group of several lateral shoots that make the plant unsuitable for sale.
Biology/life-cycle: There can be two generations in the south of Europe, but only one further north. There,

the life cycle is as follows: adults emerge in June-July in central Europe. The female lays groups of one to three eggs near the central vein on the underside of the leaf. The young caterpillar hatches 8 to 15 days later, and mines a tiny tunnel into the leaf, feeding on the parenchyma. Shortly before leaf-fall, they disperse to overwinter in small cracks or crevices of the trunk or branches. In spring, the caterpillars leave their shelters and occupy young shoots or buds. Damage can only be seen externally from four to ten days after they begin feeding, when a cone of brown frass seeps from the entrance hole. Furthermore, at the attacked sites, the branches wither and are more fragile. The size of these galls varies from one clone to another. At the end of their development the caterpillars leave the stems and move towards the trunk, or drop on the ground, where they pupate. The adults appear 12 to 17 days later.

Control: The best control method is to grow less vulnerable cultivars, to prune away the attacked branches and to remove the most seriously damaged trees. The removal of ground vegetation and the avoidance of dry and sandy soils also decrease the risks of *Gypsonoma* spp attack. Chemical control is possible against the adults during oviposition, against young caterpillars just after hatching, and during their dispersal in autumn.

Hyphantria cunea (Drury) (Lepidoptera, Arctiidae)

Hyphantria cunea adults

Hyphantria cunea larva

Hyphantria cunea damage

Hyphantria cunea defoliation

Origin and Global Distribution: *Hyphantria cunea* is widely distributed in North America including Canada. It has also become established as an introduced species in central and southeastern Europe, Japan and Korea.

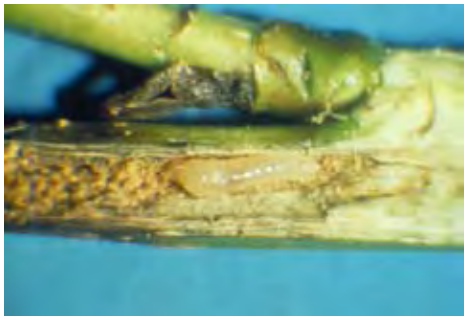
Description: This moth, with a wingspan of 2 to 3cm, has white wings that are sometimes marked by black spots. There is also one form with completely white wings. The mature caterpillar is 3 to 4 cm long, yellowish with a large dark and irregular stripe on its back. The head is black and the body is covered by tufts of long hairs.

Damage: Larvae are polyphagous, feeding mostly on fruit trees and numerous forest species.

Biology/life-cycle: There are one to three generations a year. The females lay clusters of several hundreds of eggs covered with silk on the lower surface of leaves in May, and again in July if conditions are favourable. The eggs hatch after one to three weeks. After eclosion the caterpillars remain together in groups and web several leaves together with silken threads to form a nest. During the last two larval stages, they disperse all over the tree's foliage, which they devour, leaving only the large veins, before pupating in a cocoon often in litter in the soil. If conditions are favourable, the pupa metamorphoses into a moth a few days later. Otherwise it overwinters.

Control: *H. cunea* has considerable economic importance owing to its remarkable proliferation from the great number of eggs laid and the variable number of annual generations depending on conditions. *Bacillus thuringiensis, Beauveria bassiana* and *Metarhizium anisopliae* yield fairly good results, giving mortality of between 45 and 100 % depending on product, dosage, and the larval stage.

Janus spp. (Hymenoptera, Cephidae)
Janus abbreviatus (Say)
Janus luteipes (Lepeletier)



Janus abbreviatus larva in gallery

Janus abbreviatus injury to shoot

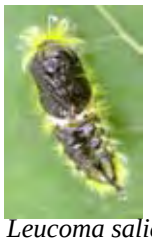
Origin and Global Distribution: *Janus abbreviatus* can be found on willows and poplars over the whole eastern part of the United States and in southern Canada; *J. luteipes* is common in central and southern Europe.
Description: The adult sawfly is 6-9mm long, almost completely black, with a long, narrow body. Larvae are only slightly coloured.
Damage: Branches, already weakened by oviposition scars, are killed by tunnelling larvae. The branch above the damage desiccates, dies and often breaks.
Biology/life-cycle: These species have a similar life cycle. The adults fly in mid-summer. The eggs are laid in ring-shaped perforations made by the females in the young, as yet non-lignified branches of poplars and willows. The larvae bore descending tunnels into the wood. The insect spends winter in its tunnel protected in a cocoon. There is generally only one generation a year, but there can be up to three if conditions are favourable.
Control: Damage is minimised by good growing practices. If necessary, chemical treatments can be applied during the adult flight period.

Leucoma (= Stilpnotia) spp. (Lepidoptera, Lymantriidae)
Leucoma (= Stilpnotia) candida (Staudinger)
Leucoma (= Stilpnotia) salicis (Linnaeus)

Leucoma salicis adult

Leucoma salicis cluster of eggs

Leucoma salicis larva



Leucoma salicis chrysalis

Leucoma salicis damage

Leucoma salicis defoliation

Leucoma salicis parasitoid: *Telenomus nitidulus*

Origin and Global Distribution: *Leucoma salicis* is very widely distributed in the palearctic region. Its distribution range covers all of Europe, the Middle East, Japan and America as far as British Columbia. *L candida* is common in China.

Description: The moth is white. The female has a wingspan of 3.5 to 5 cm and hair-like (filiform) antennae, while the male is smaller with feather-like (pectinate) antennae. Final instar larvae can be 5 cm long. They are black with a row of white or yellow spots on their back and red-orange warts covered with tufts of hair on their sides. The pupa is yellow, rapidly turning to black.

Damage: *L. salicis* develops on willows and especially poplars, feeding poplars of all sizes even in nurseries. Females rarely disperse over long distances so an infestation does not spread quickly. A defoliated poplar stand has a good chance of recovery and will quickly regrow new lighter coloured and smaller leaves. There is nevertheless a production loss of between 3 to 4 m^3 per hectare from a single defoliation.

Biology/life-cycle: The developmental cycle is generally annual, but there may be up to three generations a year under favourable conditions. The adults hatch during the summer. The males are active fliers but the females fly very little. The females lay their eggs on the bark at any height, or on the host leaves, or on any other support. The egg mass is covered with a whitish mucus. The larvae hatch about twelve days later and initially feed on the underside of leaves. They overwinter as second instars inside silken shelters within bark cavities, often at the base of the trunk. The following spring, the caterpillars crawl up to the tree canopy and devour practically all the leaves, before pupating in early summer. Pupae are attached to leaves.

Control: In central Europe, infestations are checked by numerous enemies including insects such as *Telenomus nitidulus,* viruses or even birds such as woodpeckers, cuckoos or tits; or by climatic factors. The overwintering stage is very vulnerable to extreme cold and violent rain. Although complete defoliation is impressive, chemical control is hardly justified as such events are restricted to roadside plantations. The principal control method is to select less vulnerable clones. The most susceptible species are: *Populus alba, P. deltoides, P. nigra*, as well as the hybrids *P.* X *euramericana* (cultivars Robusta, Gelrica and Serotina, among others). Cultivars of *P. trichocarpa* are less damaged. Mineral manures can also reduce the number of attacks by increasing larval mortality and decreasing the fecundity of survivors. Poplar plantations with an under-plantation of alders are attacked less, as the caterpillars end up on the trunks of this species during dispersal and risk dying of starvation. If an intervention seems essential, priority should be given to biological means (*Bacillus thuringiensis)* or to pesticides with low ecological impact. Sprays should be applied when the larvae are close to the soil, i.e., just after the overwintering period when the caterpillars disperse towards the foliage, or in autumn when they reach their winter shelters.

Melanophila picta Pallas (Coleoptera, Buprestidae)

Melanophila picta
adult

Melanophila picta
larva in gallery

Origin and Global Distribution: *Melanophila picta* is found in the hot areas of the Mediterranean and the Middle East, reported from Bulgaria, Spain, the south of France, Italy, Pakistan, Portugal, and in Turkey.
Description: Adults are between 10 and 15 mm in length and are bronze or copper in colour with yellow spots that are highly variable in size and shape.
Damage: The beetle only attacks trees under physiological stress, such as those growing on unsuitable terrain or under water stress. Young trees and especially plants in their first year of plantation are most susceptible. Spring plantations are always attacked more than autumn ones, as they have no time to adapt to the new conditions and repair the physiological shock of transplantation before *M. picta* swarming. There is no great difference in specific resistance to certain clones or species. Most varieties can be attacked when they suffer from physiological stress. In Iraq, *P.* X *euramericana* and *P. euphratica* are particularly favoured whereas *P. nigra* is slightly less vulnerable to attacks from *M. picta*.
Biology/life-cycle: The adults hatch in May - June and swarm when the temperature reaches 20-22°C. The female lays her eggs one by one in tiny cracks in the bark. The larvae hatch 8-12 days later and dig galleries into the wood with no distinctive design. Larvae can be detected thanks to the colouring of the bark: the outside becomes brownish as though it had been smeared with oil. The larvae hibernate in their galleries and complete their metamorphosis in April - May of the following year.
Control: The best control measure is to plant long cuttings on good well-irrigated soil at the end of the winter. If required, spraying the trunks during swarming yields good results.

Mordwilkoja vagabunda Walsh (Hemiptera, Aphididae)

Mordwilkoja vagabundus injury

Origin and Global Distribution: *Mordwilkoja vagabunda* is a widely distributed aphid in North America.
Description: Adults (4-5 mm long) are yellow-green, pear-shaped aphids, with relatively long antennae and delicate, membranous wings. Nymphs are wingless, smaller and paler than adults.
Damage: It feeds on the sap of *Populus* spp. as primary host, causing galls on the branch ends that are initially shiny green and subsequently black and lignified.
Biology/life-cycle: In Canada, this aphid is common on *P. tremuloides*. It is a holocyclic species. The winged females leave *Populus* spp. during the summer months to infest another, as yet unknown, host. In autumn, another winged generation returns to the poplars and reinfests the galls. Certain trees tend to be infested year after year while others are not.
Control: Infestation can be reduced by clipping and destroying galls by hand. If necessary, an insecticide recommended for aphids can be applied in the spring to control emerging aphids.

Nematus spp. (Hymenoptera, Tenthredinidae)
Nematus oligospilus Förster
Nematus melanaspis Hartig
Nematus miliaris (Panzer)
Nematus frenalis Thompson

Nematus oligospilus adult

Nematus melanaspis cluster of eggs

Nematus oligospilus larva

Nematus melanaspis larvae

Nematus oligospilus defoliation

Origin and Global Distribution: There are many different *Nematus* species. *N. oligospilus*, which is common in Europe, was first reported in Argentina and in Chile in 1983-84 (as *N. desantisi*), in the Republic of South Africa in 1993-94 and in New Zealand in 1997. It is also native to North America where it is common on willows. *N. melanaspis* and *N. miliaris* are found in Europe and northern Asia, and *N. frenalus* in China.

Description: Adult sawflies with an elongate body from 5-10 mm long, depending on species. Colour is very variable (yellow, green, with more or less extensive black markings). Larvae are equally variable, up to 20 mm long in some species, often yellowish with dark markings on each segment. They have 'false legs' or 'prolegs' on most abdominal segments.

Damage: *Nematus* species are all defoliators with similar life cycles. *N. oligospilus* in S. America mainly attacks *S. humboldtiana*; in South Africa it attacks imported willows *Salix babylonica* and *S. fragilis,* but not *S. mucronata,* which is indigenous, or *Populus deltoides.* In New Zealand it also attacks imported willows (there are no native Salicaceae). In both countries it has already caused major damage to willows used as windbreaks. If attacks are repeated for several years in succession, the end branches and then the whole tree dry out gradually and the tree can die. Experiments are underway to find out if resistant clones exist.
N. melanaspis and *N. miliaris* are found in Europe and northern Asia, and can completely defoliate willows and poplars. In Poland, in order of preference *N. miliaris* attacks *Salix elegantissima* > *S. caprea* > *S. alba* > *S. daphnoides* > *S. repens. S. amygdalina* is not attacked. *N. frenalus* is found on willows in China.

Biology/life-cycle: All these species have a similar life cycle. There are usually between one and three annual generations depending on conditions. They overwinter in the larval stage in a cocoon on the ground. Eggs are laid in clusters of 20 to 100 on the upper or lower face of leaves. They are about 1 mm in diameter, and may be clear or green and shiny. Hatching occurs 3 to 10 days after laying. The larvae, which are generally green-yellow with three or four longitudinal stripes, devour the whole leaf, leaving only the central and secondary veins. The Southern Hemisphere populations of *N. oligospilus* are entirely female.

Control: There are fortunately many natural enemies that manage to control populations of *Nematus* spp., at least in their countries of origin.

Operophtera spp. (Lepidoptera, Geometridae)
Operophtera bruceata (Hulst)
Operophtera brumata (Linnaeus)

Operophtera brumata adult female

Operophtera brumata adult male

Operophtera brumata larva

Operophtera brumata defolation

Origin and Global Distribution: *Operophtera brumata* is distributed in Europe and Asia, and was introduced accidentally into the Maritime Provinces of Canada as well as the west coast of British Columbia. *O. bruceata* originates from North America.

Description: For both species, the female has only wing stubs and is unable to fly, while the male has perfectly developed grey wings. The caterpillars of *O. bruceata* are pale green pale with lateral yellow stripes and measure approximately 25 mm at the last stage. Those of *O. brumata* are green with a dark dorsal stripe and light coloured stripes on the flank. The head is dark coloured. They both possess the typical shape of looper caterpillars.

Damage: *O. bruceata* is mainly associated with *Acer saccarum* and *Fagus gandifolia* in the eastern part of its distribution range and with *Populus tremuloides* and *Salix* spp. in the western part. *O. brumata* is definitely more polyphagous. This insect also attacks poplars as well (*P. deltoides X P. nigra)* as hornbeams, oaks, elms, maples or fruit trees. In the event of overpopulation, the two species can cause complete defoliation. If this happens in spring, the poplars can easily recover but the tree is weakened, which can cause the shoots to dry out and the tree to die after drought and the activity of secondary pests.

Biology/life-cycle: There is a single annual generation. The eggs are laid in autumn separately or in small groups, in bark cavities of the host tree or on the branches near the foliar buds. The caterpillars hatch in the following spring. The young caterpillars can bore into the buds and kill them. The older caterpillars feed on leaves and attach them loosely together in order to make a shelter. In June, the mature caterpillars form cocoons among the leaf litter or in the ground.

Control: Interventions using treatments of *Bacillus thuringiensis* should be the exception, and only considered during outbreaks accompanied by unfavourable factors (drought in particular). Monitoring populations using trees traps with glue rings, or pheromone traps can assist decisions. In Canada *Operophtera brumata* is controlled by two introduced parasites, *Cyzenis albicans* and *Arrypon flaveolatum.*

Orgyia spp. (Lepidoptera, Lymantriidae)
Orgyia antiqua (Linnaeus)
Orgyia thyellina Butler

O. antiqua adult female

O. antiqua adult male

O. antiqua cluster of eggs

O. antiqua larva

Origin and Global Distribution: Two species can be dangerous to willows and poplars. *Orgyia antiqua*, very widely distributed all over Europe, North America and Japan, and *O. thyellina*, originally from Japan, Korea, China and Russia. *O. thyellina* was accidentally introduced into New Zealand in 1996, but was eradicated by 1998.

Description: The male of *O. antiqua* is brown - yellow with two half-moon shaped white spots on the back wings. The wingspan is 3 to 3.5 cm. The females have only stubs for wings. The caterpillars of the last stage reach 2.5 to 3 cm. They are black and hairy with four large tufts of brown-yellow hair on both sides of the flank, two tufts of black hair forming the "horns" and a tuft of black hair for a "tail".

The male of *O. thyellina* is grey-black with a white spot on each wing and measures about 13 mm. The female is larger and whitish in colour with a dark coloured spot on the wings. The first and second female generations have wings; the third has wing remnants and cannot fly. The caterpillar of the last stage measures approximately 3 cm and is very hairy and dark coloured with orange stripes on the flank and four tufts of light-coloured hair on the back.

Damage: These two species are extremely polyphagous, attacking both coniferous and deciduous trees. Defoliation can be severe and cause growth loss. *O. thyellina* is not regarded as dangerous in its countries of origin but was considered a major threat to orchards and forests in New Zealand.

Biology/life-cycle: The caterpillars of *O. antiqua* hatch in spring and actively feed on young leaves. The chrysalids are small silk cocoons that are difficult to find. The second generation can appear in mid-July. Winter is spent in the egg stage. There can be up to three annual generations of *O. thyellina*. The female lays 50 to 300 eggs that hatch after a few weeks. These eggs are laid on leaves, branches, dead leaves that are still attached to the tree, garage or house roofs. At the beginning of autumn, the apterous females lay their eggs directly on the chrysalis whence they emerged. The latter will hatch only the following spring.

Control: In the event of small-scale infestation on young plants, the caterpillars (which sting) can be removed manually. If necessary, it is possible to use insecticides on the young caterpillars. Eradication of *O. thyellina* in New Zealand was accomplished with the use of aerial spraying of *Bacillus thuringiensis*.

Paranthrene tabaniformis (Rottemburg) (Lepidoptera, Sesiidae)

Paranthrene tabaniformis adult female

Paranthrene tabaniformis adult male

Paranthrene tabaniformis larva in gallery

Paranthrene tabaniformis exuvia of chrysalis

Paranthrene tabaniformis gall

Paranthrene tabaniformis exit hole

Origin and Global Distribution: *Paranthrene tabaniformis* is widespread in central and southern Europe, North Africa and Asia, in particular in China, the north of India, and in Pakistan. It can also be found in across Canada and in Russia and Finland.

Description: The adult insect has a black body with three or four yellow rings on the abdominal segments and has a wasp-like appearance. The front wings are brown and the back ones are transparent. The wingspan is 25 to 35 mm.

Damage: *P. tabaniformis* lives on all cultivated poplars, but willows are seldom attacked. This insect causes particularly heavy damage in nurseries on one-year old plants, and less frequently on two-year old plants. In Canada it is rarely found in natural forests but is common in nurseries. The presence of *P. tabaniformis* caterpillars is observed by a swelling of the trunk in a gall shape, sometimes pierced with an exit hole just underneath the crown. Tree growth is disturbed, and they also become also much more fragile and can break when exposed to the wind.

Biology/life-cycle: Egg-laying can occur throughout the whole summer, but primarily in July and August in central Europe and Canada. The eggs are laid on branches close to wounds or cracks in the bark of young trees. Immediately after hatching, the caterpillar, creamy white with a dorsal stripe and two dark sides, bores a longitudinal gallery of 3 to 4 cm long into the wood. Larvae can hibernate once or twice depending on the climate before entering the pupal stage. At the end of its evolution, the caterpillar can measure up to 4 cm. In spring, pupation takes place in a cocoon close to the tunnel opening. After about twenty days, the adult exits through an opening made for this purpose by the larva.

Control: In nurseries, it is possible to control *P. tabaniformis* chemically if applications are made at the right moment and are repeated during the whole flight period. Pheromone traps make it possible to know the adult flight periods. In spite of laboratory and field research, no clonal difference has been observed. The balsam poplars (*P.* X *trichocarpa*) are particularly affected. To prevent attack, it is important to stimulate rapid poplar growth by planting trees on appropriate sites, with fertilization, and by choosing fast-growing clones that are able to heal wounds quickly. Another means of prevention is to avoid trunk wounding or pruning during the flight period. Infested trees or branches must be removed before the adults hatch in order to avoid further infestation.

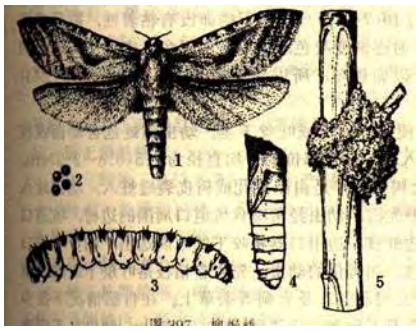
Parthenolecanium corni (Bouché) (Hemiptera, Coccidae)

Parthenolecanium corni adults

Origin and Global Distribution: This scale insect is European in origin but is widely found in North America and in New Zealand.
Description: The adult female is 3-6mm long and 2-4mm wide, dark brown but very variable. Larvae are dark coloured.
Damage: In the event of heavy attack, trees are strongly weakened. In Canada the scale is reported on a number of hardwood tree species though serious damage not reported.
Biology/life-cycle: *P. corni* is highly polyphagous. The active stages feed on leaf sap. There is only one annual generation. Reproduction is mainly carried out by parthenogenesis although males are sometimes present. The eggs are laid at the beginning of summer, under the female. The larvae are mobile and feed by sucking the leaf veins. In autumn, they migrate to the branch bark to hibernate.
Control: Infested branches must be pruned and destroyed. If necessary, an insecticide recommended for scale insects can be applied.

Phassus (= *Endolita*) *excrescens* Butler (Lepidoptera, Hepialidae)

Phassus excrescens adult



Phassus excrescens stages

Origin and Global Distribution: *Phassus excrescens* is common in Japan and Korea
Description:
Damage: *P. excrescens* is polyphagous. The caterpillar penetrates the wood and bores many tunnels. The attack is recognized by a plug of frass connected by silk threads at the entrance to the hole.
Biology/life-cycle: Adults emerge from August to October. Females lay up to 6,000 eggs, which they drop on the ground near the tree hosts. The young caterpillars hatch the following spring, and initially feed on grasses and annual plants growing at the foot of the tree, then penetrate the lower part of the trunk. The biological cycle lasts from 1 to 2 years.
Control: The best control measure is to remove ground vegetation around the poplars.

Phloeomyzus passerinii (Signoret) (Homoptera, Aphididae)

Phloeomyzus passerinii adult

Phloeomyzus passerinii injury on the trunk

Origin and Global Distribution: *Phloeomyzus passerinii* is a common aphid in Europe, though much less common in the United Kingdom. It can also be found in North Africa and South America, as well as in China.

Description: This plant aphid (*c.*0.5-1 mm) is yellow-green in colour. It is covered with a light covering of grey-white concealed under an abundant secretion of white waxy filaments.

Damage: The insect affects poplars of any age but 6-to-8 year old trees are generally the most vulnerable to infestation. Young poplars, where the crowns do not touch, are practically untouched by infestation. The aphid attacks lignified tissue, feeding on parenchymatous bark material while simultaneously injecting toxic saliva to cause necrosis of the occupied bark section. Damaged trees have a reddish, swollen trunk. In the event of overpopulation, great portions of bark can die, causing the death of subjacent wood. If sap circulation is completely halted, the tree can die.

Biology/life-cycle: The aphid colonizes the trunks, generally on the shaded side. It tends to colonize smooth-trunked varieties.

Control: To minimize damage from these insects it is best to space the poplars far apart, plant them in sunny places, and to cultivate resistant varieties. In Belgium, *P. serotina erecta* is sometimes prone to relatively serious attacks. *Populus* X *euramericana* cv. Robusta and *P. deltoïdes* spp. *angulata* appear resistant. Certain clones, used in several countries such as I-214, I-45/51, Boccalari, BL Costanzo, Pan, Triplo are vulnerable to attack, while Lux, Harvard, Luisa Avanzo, San Martino, Onda, Dvina, Neva, Lena, Eridano, Villafranca are resistant. To obtain accurate results, resistance tests should be run on cuttings during growth periods.

Phratora (= *Phyllodecta*) spp. (Coleoptera, Chrysomelidae)
Phratora purpurea Brown
Phratora vitellinae (Linnaeus)
Phratora vulgatissima (Linnaeus)

Phratora vitellinae adult

Phratora vitellinae cluster of eggs

Phratora vitellinae larvae

Phratora vitellinae damage

Phratora vulgatissima overwintering adult

Phratora vulgatissima eggs and larvae

Origin and Global Distribution: *Phratora* is a very widespread genus found in Europe, North America and Russia. *Phratora purpurea purpurea* has a transcontinental distribution across the range of *Populus tremuloides* in North America.

Description: The two most frequent species are: *Phratora vulgatissima* - metallic blue, 3.5 to 5 mm long; and *P. vitellinae* - bronze coloured with blue reflections and 3.5 to 4.5 mm long. *Phratora purpurea purpurea* is dark metallic green or brown.

Damage: Adults and larvae of this genus feed on willows as well as poplars and tend to attack young plants. The order of preference for *P. vitellinae* are: *Salix nigricans* > *S. purpurea* > *P. tremula* > *Populus trichocarpa* > *P. nigra* > *S. alba* > *P. deltoides* X *nigra* > *P. deltoides* X *trichocarpa*. This leaf beetle has never been found on willows with trichomes on the lower leaf side. *Phratora tibialis* feeds on *Salix* only. In the event of an outbreak, there can be considerable damage. When foliage is attacked, a dramatic loss in growth can result, which is especially serious in nurseries and young plantations. *Phratora purpurea purpurea,* while not of economic importance is a gregarious skeletonizer during the growing season.

Biology/life-cycle: Depending on conditions, these defoliating insects can have up to three annual generations. Eggs are laid in plates on the lower side of the leaf. The larvae hatch after approximately 6 days and remain clustered. They feed on the leaf, only leaving the veins and the upper epidermis. After the final larval stage, they migrate to the ground for the pupal stage. The adult emerges 10-12 days afterwards. As egg laying is spread out over the season, generations can overlap.

Control: The best prevention is to select resistant poplars, but treatment of the trees with a contact insecticide during the adult feeding and laying period can also yield good results.

Phyllobius spp. (Coleoptera, Curculionidae)
Phyllobius oblongus (Linnaeus)
Phyllobius betulae Linnaeus

Phyllobius betulae adult

Phyllobius oblongus adult

Phyllobius betulae damage

Origin and Global Distribution: These are very common insects in Europe, as far as Russia, Iran and Turkey. *P. oblongus* was introduced into North America and was first reported in 1923.
Description: These are small short-snouted weevils. *P. oblongus* is 3 to 6 mm long with a brown body and a narrow black neck. *P. betulae* is 3.4 to 6 mm long with a brown or black body and blue, green or golden squamules.
Damage: The adult insect can cause damage to leaves, which is rarely serious unless there is overpopulation.
Biology/life-cycle: There are very many species of *Phyllobius*, most of which are polyphagous. Adult *Phyllobius* feed on leaves of a number of hardwood trees (*Populus, Betula, Quercus, Fagus, Salix),* while the larvae feed on the roots of very diverse plants, including grasses and annual plants.
Control: Powdering with contact insecticides can be applied successfully to young plants.

Phyllocnistis spp. (Lepidoptera, Phyllocnitidae)
Phyllocnistis unipunctella (Stephens, 1834)
Phyllocnistis labyrinthella (Bjerkander, 1790)
Phyllocnistis populiella Chambers, 1875

Phyllocnistis unipunctella adult

Phyllocnistis unipunctella larva in mine

Phyllocnistis unipunctella mine

Phyllocnistis unipunctella gallery

Origin and Global Distribution: In Europe, the main species found are *Phyllocnistis unipunctella* and *Ph. labirinthella*. *Ph. populiella* can be found in Canada.
Description: *Phyllocnistis* spp. are small butterflies with a wingspan of 7 to 8 mm and narrow and bordered front wings, whitish in colour with ochre tips. The back wings are even narrower and have a broad fringe.
Damage: These insects skeletonize leaves, leaving them a whitish colour with areas resembling a slug trails. Fairly often, the leaf mine skirts an important vein or the edge of the leaf. Trees of all ages can be attacked but the varieties of *P. nigra* and *P. deltoides* X *P. nigra* are preferred, while those of the groups *P. trichocarpa* and *P. trichocarpa* X *P. deltoides* are attacked less.
Biology/life-cycle: This butterfly can have up to three annual generations with the first generation appearing at the beginning of the summer. The green-grey eggs are laid individually on the lower face of the leaf. The caterpillars hatch after 6 to 9 days. They are white-yellow, small and very flat. They have no thoracic or abdominal legs but have side protuberances to help them move around. The young caterpillar penetrates the cuticle and digs a sinuous tunnel from 6 to 10 cm. It feeds on sap, which it finds in the cells for approximately two months before pupating within a white cocoon at the end of the tunnel.
Ph. xenia (= *labyrinthella*) and *Ph. saligna* live on willows.
Control: Comparative experiments have shown that *P. unipunctella* is less abundant on sandy ground than on muddy and wet ground. It has been suggested that these types of terrain modify the leaf tannin composition and hence insect mortality.

Phyllonorycter (= *Lithocolletis)* spp. (Lepidoptera, Gracillariidae)
Phyllonorycter apparella Herrich-Schäffer
Phyllonorycter iteina (Meyrick)
Phyllonorycter nipigon (Freeman)
Phyllonorycter populiella (Chambers)
Phyllonorycter populifoliella (Treitschke)
Phyllonorycter salicicolella (Sircom)
Phyllonorycter salicifoliella Chambers
Phyllonorycter scudderella (Frey & Boll)

Phyllonorycter salicicolella adult

Phyllonorycter spp. mines

Phyllonorycter spp. damage

Origin and Global Distribution: *Phyllonorycter* spp. are small moths found in North America, Russia, Europe, India and Pakistan.
Description: *Phyllonorycter* spp. have a wingspan of 5 to 7 mm and are blue-grey with metallic sheens. The caterpillars are also tiny and have a flattened shape. They possess neither thoracic nor abdominal legs.
Damage: The larval form is an adaptation to its unusual life within the thickness of foliar parenchyma. Indeed, immediately after hatching, the caterpillars enter the leaf where they feed and gradually hollow out an oval space. The leaf epidermis above the feeding larva takes on a brown-yellow colour and is easily removed as an oval blister, revealing frass and the caterpillar. The caterpillar pupates in its leaf mine, out of which the chrysalis projects so that the moth can emerge without damaging its wings.
Biology/life-cycle: Depending on conditions, the various species can have two to three generations a year. Some species are polyphagous, while others are very host specific. There are numerous species of *Phyllonorycter*. In Europe, *P. populifoliella* is the most damaging species, particularly on *Populus nigra*. *P.* also causes damage to *Salix* spp. and *P. tremula*. In Russia, both *P. populifoliella* and *Cameraria* (=*Lithocolletis*) *obliquifascia* can be found on *Salix* spp. In India and Pakistan, *Cameraria (=Lithocolletis) virgulata* is polyphagous while *P. iteina* (=*P. eophanes)* feed on *Salix tetrasperma*. In North America, *P. apparella (= P. ontario and =P. tremuloidiella), P. nipigou* and *P. populiella* are found on *Populus* spp., and *P. scuolderella (=P. salicivorella)* and *P. kenora* on *Salix* spp.
Control: If necessary, systemic insecticides, penetrating the leaves and tunnels, can help control developing larvae and even pupae.

Phytobia (= *Dizygomyza*) spp. (Diptera, Agromyzidae)
Phytobia barnesi (Hendel)
Phytobia cambii (Hendel)
Phytobia carbonaria (Zetterstedt)

Phytobia cambii adult

Phytobia cambii larva

Phytobia cambii pupae

Phytobia cambii injury in wood

Phytobia cambii injury in wood

Origin and Global Distribution: These small Diptera can be found across Europe.
Description: Adults are dark coloured flies, 4-5mm long. Filiform, wite-yellowish larvae in the wood may reach up to 20mm in length.
Damage: They cause considerable damage to poplars and willows in the northern portion of their range. The larvae of *P. barnesi* generally attack willows, particularly *Salix alba* and *S. viminalis*. Damage passes unobserved until harvesting. Wood quality is impaired by the presence of long brown galleries and by the healing parenchyma formed, which weakens the wood, especially veneering. The presence of *Phytobia* makes willows unusable for basket making.
Biology/life-cycle: There are several very close species (*P. barnesi, P. cambii, P. carbonaria*) with similar behaviour. There is one generation a year. The adults, tiny flies of approximately 4 mm, fly at the beginning of the summer. The female lays one egg at a time into the bark of the host tree using her retractile ovipositor. The larvae are thread-like and whitish in colour; their skin carries fine warts and backward-combed spines. Once hatched, they gnaw a tiny sinuous gallery in the sapwood and cambium, which gets wider with time. At maturity, the larvae measure between 15 and 30 mm. The pupa is formed in the ground where it hibernates. The complete cycle, from egg to pupae, lasts only two months; but the adult hatches at the end of the following spring.
Control: Control is technically difficult and prohibitively expensive. Various important pathogens, including *Erwinia salicis*, are often associated with these insects' galleries.

Platypus sulcatus Chapuis (Coleoptera, Platypodidae)

Platypus sulcatus adult female (left) and male (right)

Platypus sulcatus entrance hole

Platypus sulcatus bark injury

Platypus sulcatus injury in plantation

Origin and Global Distribution: *Platypus sulcatus,* a polyphagous species, causes economically important damage in South America, particularly in Argentina.
Description: Adults are dark brown beetles, rather elongate, about 5mm long. Larvae are white-yellowish in colour.
Damage: *P. sulcatus* attacks poplars and more rarely willows. The insects attack healthy trees of large diameter (above 15 cm), or, more rarely, trunks with a minimal diameter of 8 cm. Fungal mycelium augments the physical damage by staining the wood black at the perforation site.
Biology/life-cycle: The cycle has four larval stages, a pupal stage then adulthood. The cycle takes place almost entirely inside the tree, except mating, which occurs in the open air. In large diameter trunks, the males build galleries and release pheromones to attract the females. Once fertilized, the female penetrates the trunk and prepares a substrate for fungal (*Ambrosia*) cultivation, which will constitute the first food source for larvae. The female lays her eggs at the end of the gallery. The larvae, after having fed on fungal mycelium, attack the tree by drilling galleries from October-November until March-April. The adult galleries are radial and are located on the same horizontal level perpendicular to the trunk. The larvae galleries are perpendicular to the adult ones and parallel to the trunk.
Control: No substantial differences in attack have been observed among poplar cultivars. In the event of large-scale attack, positive results can be achieved by applying a mixture of lime and sulphur diluted in water to the trunk as an environmentally benign deterrent.

Polydrusus (= Polydrosus) impressifrons (Gyllenhal) (Coleoptera, Curculionidae)

Polydrusus impressifrons adult

Polydrusus impressifrons damage

Origin and Global Distribution: This species is found in Europe (Spain, France, Italy, ex-Yugoslavia, Hungary), in eastern Canada, and northeastern United States.
Description: *P. impressifrons* is a metallic-green beetle.
Damage: The larvae of *Polydrusus* spp., like those of *Phyllobius,* eat the roots of various annual herbaceous plants, while the adults feed on tree leaves (*Populus, Salix, Quercus*). During outbreaks, these beetles can damage young poplar plantations.
Biology/life-cycle: *P. impressifrons* is found on various hardwood trees such as poplars, oaks, birches and beeches.
Control: If necessary, contact insecticides can yield good results.

Porthetria (= *Lymantria*) spp. (Lepidoptera, Lymantriidae)
Porthetria dispar (Linnaeus)
Porthetria obfuscata Walker

Porthetria dispar female adult

Porthetria dispar male adult

Porthetria dispar cluster of eggs on the bark

Porthetria dispar larva

Origin and Global Distribution: *Porthetria dispar* species are found throughout the northern hemisphere. The insect introduced was into North America in the 19th century. In India, it is rare and causes little economic damage.

Description: Full grown larvae of *P. dispar* reach 4 to 7 cm in length with tufts of long brown hairs coming out of warts; their front is blue, almost black, and the back is red. The adults have a strongly marked sexual dimorphism. The females have a wingspan of 3.5 to 6 cm and are dirty white with darkish spots marking the border. The males are brown - grey with irregular spots and transverse bands on the front wings; their wingspan does not exceed 5 cm. The adults of *P. obfuscata* have also a strongly marked sexual dimorphism..

Damage: *P. dispar* is a voracious defoliator of hardwoods including oak, hornbeam, beech and fruit trees with a wide host range, but *Quercus* is its primary host in North America. On the other hand, *P. obfuscata* causes much more serious damage to fruit trees and willow plantations in India and Pakistan. *P. obfuscata* has a clear preference for *Salix alba* and *Populus nigra.* The caterpillars of *P. dispar* are extremely voracious. After complete defoliation of these species, they can attack other species, in particular poplars and willows or certain conifers. Damaged trees generally produce a second annual foliation but, despite this regeneration, they nevertheless suffer an important loss in production.

Biology/life-cycle: The adults of *P. obfuscata* are active at the end of June - beginning of July. Females lay their eggs near to their pupation site in a compact mass covered in yellow hair. The caterpillars hatch the following spring and ascend into the foliage. They tend to be gregarious and the species is univoltine. *P. dispar* is also univoltine. Adults emerge from July to September. The females hardly leave the pupal site and eggs are laid in clusters of 100 to 800 eggs covered with a kind of brown and silky cushion from the female's abdominal cavity. These eggs are laid on the trunks of the tree hosts, on barriers, walls or on ground litter. The eggs hatch only in the following spring. Still grouped together, the young caterpillars climb towards the leaves. The larvae are dispersed from one tree to another by the wind during the first larval stage. They completely devour all the foliage by traveling from branch to branch. Feeding is completed by July and the larvae, which are 35-60 mm long, seek sheltered spots to pupate. The adults emerge 10 to 20 days later.

Control: Preventive control requires permanent monitoring of population levels by observing oviposition. If necessary, one effective control measure is to use *Bacillus thuringiensis* in spring on young caterpillars present on the trunks, still close to ground level. Later in the season, the insects are dispersed all over the foliage and difficult to reach. In North America, the insect is often controlled by aerial application of Bt, but in much of Canada the insect has recently been brought under control by the naturally occurring NP virus and by the introduced fungus, *Entomophoga maimaiga*.

Sesia (=Aegeria) apiformis Clerck (Lepidoptera, Sesiidae)

Sesia apiformis adults mating

Sesia apiformis eggs

Sesia apiformis larva in gallery

Sesia apiformis chrysalis

Sesia apiformis exit holes at the base of the trunk

Origin and Global Distribution: *Sesia apiformis* is found all over Europe, from Finland to the Mediterranean basin, the Middle East, Asia Minor, and China. This insect was introduced into North America and was observed for the first time in Canada in 1983.

Description: The adult has a wasp-like body with yellow and black rings. The wings are narrow, transparent with dark edges, with a wingspan of approximately 35 mm.

Damage: The result for older trees is a loss in timber due to the larval galleries. As well as being damaged, wood on the circumference becomes discolored. Root damage can encourage penetration of fungi and xylophagous insects, but this damage only affects the trunk base and thus is of lesser importance. On young trees, the galleries on the shoots can disturb growth or cause the tree to break, or die. This occurs in nurseries or new plantations and more particularly in plantations established after cutting down poplars with roots hosting large insect populations. Poplars of all ages are attacked, even very large ones. In certain areas there is a preference for young trees. Only poplars grown on stony ground are spared as the eggs need relatively high humidity to hatch. The percentage of moisture of sapwood also strongly influences caterpillar growth. There is very strong caterpillar mortality when wood becomes too dry.

Biology/life-cycle: Adults emerge in May-June, and the female lays its eggs at the foot of trees. The caterpillars hatch approximately a month afterwards. They are very mobile and penetrate into the base of the trunk or the roots, and form galleries from 20 to 50 cm long towards the roots. The life cycle lasts two years, occasionally three. The caterpillars hibernate in their galleries from October to start feeding again only the following spring. At the end of their growth cycle, the caterpillars go up to the tree neck level and weave a cocoon of wood debris. After approximately three weeks, the young adults emerge and begin flying.

Control: An under-plantation of elder trees would probably decrease *S. apiformis* attacks, because the litter of these species releases a toxic substance for the young caterpillars. If necessary, tree necks can be sprinkled with systemic insecticides or the trunk can be treated with contact insecticides at a height of one meter. Damaged trunks should be removed to avoid propagation.

Trichiocampus spp. (Hymenoptera, Tenthredinidae)
Trichiocampus viminalis (Fallén)
Trichiocampus populi Okamoto

Trichiocampus viminalis eggs on petiole

Trichiocampus viminalis larvae

Trichiocampus viminalis damage

Origin and Global Distribution: *Trichiocampus viminalis* is a widespread species, which can be found in Europe, the Middle-East and North America; while the distribution range of *T. populi* is limited to Japan.
Description: Adults are 7-9mm long with a black head, black and yellow thorax and yellow-orange abdomen. Larvae can reach 2mm in length. They have pro-legs and are yellow-green with a dark dorsal line and two black, lateral marks per segment.
Damage: All these tenthredinids act in a similar way. The larvae cause defoliation in the event of overpopulation, while the adults feed on sap exudation. The larvae of *T. viminalis* feed on various poplars, more particularly *Populus deltoides, P. nigra* var. *italica*, *P. tremula* and *P. tremuloides*, and also on *Salix* spp., but have never been observed on *P. alba*. Complete and repeated defoliation weaken the trees and can cause considerable growth loss.
Biology/life-cycle: Adults fly at the end of spring and the females deposit their eggs inside the leaves. The larvae, clear green with a dark dorsal band and black spots on each segment, hatch 7-to-12 days after laying, and remain in a cluster to feed on parenchyma, disregarding the nervures of the leaf. The insect overwinters in the larval stage, in cocoons scattered on the ground. Generally, there is one annual generation, but there can be two if conditions are favourable.
Control: If necessary, it is possible to treat with insecticides, though in North America the population is largely controlled by naturally occurring diseases.

Xyleborus (= *Anisandrus*) *dispar* (Fabricius) (Coleoptera, Scolytidae)

Xyleborus dispar adult

Xyleborus dispar adult entrance hole

Xyleborus dispar adult exit hole

Xyleborus dispar damage in wood

Xyleborus dispar damage in wood

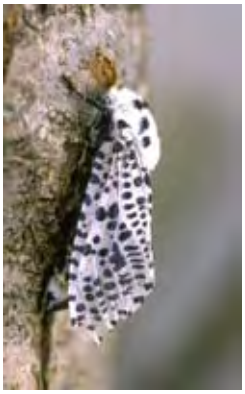
Origin and Global Distribution: *Xyleborus dispar* is widespread over the whole of Europe, North Africa and North America.
Description: *X. dispar* measures between 2 and 3.5 mm and is entirely black. The male is smaller and squatter than the female and cannot fly.
Damage: This polyphagous beetle is one of the few scolytids able to attack living trees. Attacks are mainly focused on weaker trees but healthy trees can succumb if the insect population becomes too large.
Biology/life-cycle: There is only one annual generation. On average, the visible sex-ratio is 1 male for 5-8 females. Young females emerge in April - May, and dig circular galleries that are more or less ramified and irregular in the trunks or large branches. Eggs are laid from May to July separately in side pockets oriented with the grain. The larvae develop in these galleries and feed exclusively on a symbiotic *Ambrosia* fungus. Using specialized organs, the female transports the spores of *Ambrosia* which is inoculated during boring and which quickly discolours the gallery walls, and rots the wood. After pupation, the young adults spend the winter in the oviposition galleries and breed there in the spring. The males have a very short lifespan and have rarely been observed outside the tree host. The females are contaminated with the fungus before exiting the tunneling system by the maternal entrance hole.
Control: It is very difficult to control these insects. Living inside the trees, they are sheltered from traditional chemical spraying. Preventive treatment during swarming is possible but difficult because of considerable flight duration. There are traps that can be used to define the periods of female swarming, but the best treatment is to maintain stands in good condition on suitable sites. It is also necessary to remove declining trees, which are an attractant to the beetle.

Yponomeuta (=*Hyponomeuta*) spp. (Lepidoptera, Yponomeutidae)
Yponomeuta rorella (Hübner)
Yponomeuta gigas Rebel

Yponomeuta spp. adult

Origin and Global Distribution: *Yponomeuta rorella* is found throughout Europe.
Description: Adults are micro-lepidoptera about 10mm long. The forewing is white with fine lines of black points. The caterpillar can be about 10mm long, green-brown with blackish punctuations.
Damage: *Y. rorella* causes occasional defoliation to willows and poplars in Russia, and is also an important defoliator of *Salix alba* in Europe, more particularly in Romania. Damage is limited thanks to natural enemies. *Y. gigas* feed particularly on *P. alba.*
Biology/life-cycle: The caterpillars of this small butterfly feed gregariously under the protection of a silk cover woven between the leaves. There is one annual generation. Adults appear in the middle of the summer. The caterpillars hatch and feed slightly before hiberbating at the larval stage. They restart activity in spring and chrysalize in their covers at the beginning of the summer.
Control: In general the damage caused by *Y. rorrella* is limited by natural enemies.

Zeuzera pyrina (Linnaeus) (Lepidoptera, Cossidae)



Zeuzera pyrina adult

Zeuzera pyrina larva

Zeuzera pyrina chrysalis exuvia

Origin and Global Distribution: *Zeuzera pyrina* is very common in Central Europe, the Mediterranean basin, Asia, India, and Japan. It was introduced in North America and South Africa.
Description: The adult is a metallic white butterfly with characteristic blue-black spotted wings. The female has a larger wingspan (between 6 and 7 cm) compared to the male (4.5 to 5 cm). A caterpillar can measure up to 5 cm at the end of its development. It has a whitish body with sunken spots on the back and sides. The head and two terminal segments are dark-coloured.
Damage: *Z. pyrina* is a polyphagous insect, feeding on apple trees, pear trees, poplars and willows. It is more widespread in fruit-growing areas and poses serious problems in poplar-growing zones. Trees of any size can be attacked. On poplars of average age, the presence of galleries causes the drying and rupture of damaged branches; growth is retarded and the tree is weakened. In nurseries, damage is much more serious as the presence of a single caterpillar can destroy the principal axis and lead to the death of the tree. The terminal end of the damaged branch decays drys out and breaks off.
Biology/life-cycle: The biological cycle is one to three years depending on region. Adults emerge from May to September. The female, which flies little, lays up to 800 eggs separately or in small groups in cavities of trunks and branches or in the old galleries and wounds of apple trees, pear trees, poplars and many forest species. The caterpillar hatches approximately three weeks after oviposition and initially feeds on the young branches or just under the bark but thereafter bores deeply into the wood. The caterpillars hibernate in their galleries for one to three years consecutively. The longitudinal tunnels are kept clean by ejecting the frass that can be found at the base of trees. The pupal stage occurs inside the gallery, in a cocoon of silk and wood debris. The adult emerges the following month.
Control: Chemical control is very difficult as the caterpillars are protected in their galleries and egg laying may occur throughout the growing season. It is essential to know the insects' flight periods well, using pheromone traps and ' mass trapping', in order to apply products before young caterpillars penetrate the wood. Prevention involves establishing poplar plantations on suitable terrain. It is also necessary to eliminate and burn attacked trees to halt pest propagation.

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TABLES 1 AND 2

TABLE 1 : IMPORTANCE AND BIOGEOGRAPHIC DISTRIBUTION OF INSECTS COVERED

REGION			Atl	MEur	Medit		Chin	IndM		Afr
Acarina										
Aceria parapopuli	✣									
Hemiptera										
Mordwilkoja vagabunda										
Parthenolecanium corni	✣		❍						❍	
Phloeomyzus spp.			✣	■	■					
Coleoptera										
Altica populi	❍									
Anaerea (= Saperda) carcharias			■	■	■					
Anoplophora glabripennis							■			
Anoplophora (= Batocera) horsfieldi						■	■	■		
Anoplophora malasiaca							❍			
Anoplophora nobilis							■			
Apriona cinerea						✣		✣		
Apriona germani							■			
Apriona japonica							✣			
Batocera lineolata							✣			
Bycticus populi			❍	■	✣					
Capnodis miliaris					■	■				
Chrysomela (= Melasoma) tremulae			■	✣						
Chrysomela (= M.) populi			■	■	■		❍	❍		
Chrysomela (= M.) scripta	■									
Chrysomela (= M.) vigintipunctata				✣						
Compsidia (= Saperda) populnea	✣		■	■	✣		■			
Cryptorhynchus lapathi	✣		■	■	■	✣	■			
Melanophila picta			✣	✣	■	■				
Phratora (= Phyllodecta) spp.	✣		■	✣	✣					
Phyllobius spp.			✣	❍	✣	✣				
Platypus sulcatus		■								
Polydrusus (= Polydrosus) spp.	✣			❍	■					
Xyleborus (= Anisandrus) dispar	■		■		■					
Lepidoptera										
Cerura (= Dicranura) menciana							✣			
Cerura (= D.) vinula			✣	✣	✣					
Choristoneura conflictana	■									
Clostera (= Pygaera) anachoreta						✣	✣	✣		
Clostera (= P.) anastomosis			❍	✣	✣		✣			
Clostera (= P.) cupreata						✣		✣		
Clostera (= P.) fulguriata								✣		
Cossus cossus			■	✣	■		✣			
Epinotia solandriana	✣		❍							
Gypsonoma aceriana			■	■	■					
Gypsonoma haimbachiana	✣									

REGION			Atl	MEur	Medit		Chin	IndM		Afr
Gypsonoma riparia						✣				
Hyphantria cunea				■	■		✣			
Leucoma (= Stilpnotia) salicis			❍	■	■		✣			
Leucoma (= S.) candida							✣			
Operophtera brumata	✣		✣	✣	■					
Orgyia thyellina							✣			
Orgyia antiqua	✣		✣	✣			✣			
Paranthrene tabaniformis			■	■	■		■			
Phassus (= Endoclita) excrescens							✣			
Phyllocnistis suffusella			■	✣	✣					
Phyllocnistis labirinthella			✣	✣	✣					
Phyllocnistis populiella	✣									
Phyllonorycter spp.	✣		✣	✣	✣	✣		✣		
Porthetria (= Lymantria) dispar	■		❍	■	✣	✣	❍	❍		
Porthetria (= L.) obfuscata								■		
Sesia (= Aegeria) apiformis			■	✣	✣					
Yponomeuta (=Hyponomeuta) rorella				■						
Zeuzera pyrina			✣		■					
Hymenoptera										
Janus abbreviatus	✣									
Janus luteipes			✣		✣					
Nematus spp.	✣	✣	✣	✣	✣	✣	✣	✣	✣	✣
Trichiocampus populi							✣			
Trichiocampus viminalis			✣							
Diptera										
Dasineura (Rhabdophaga) salicis	✣		❍							
Phytobia (= Dizygomyza) spp.			✣	✣	❍					

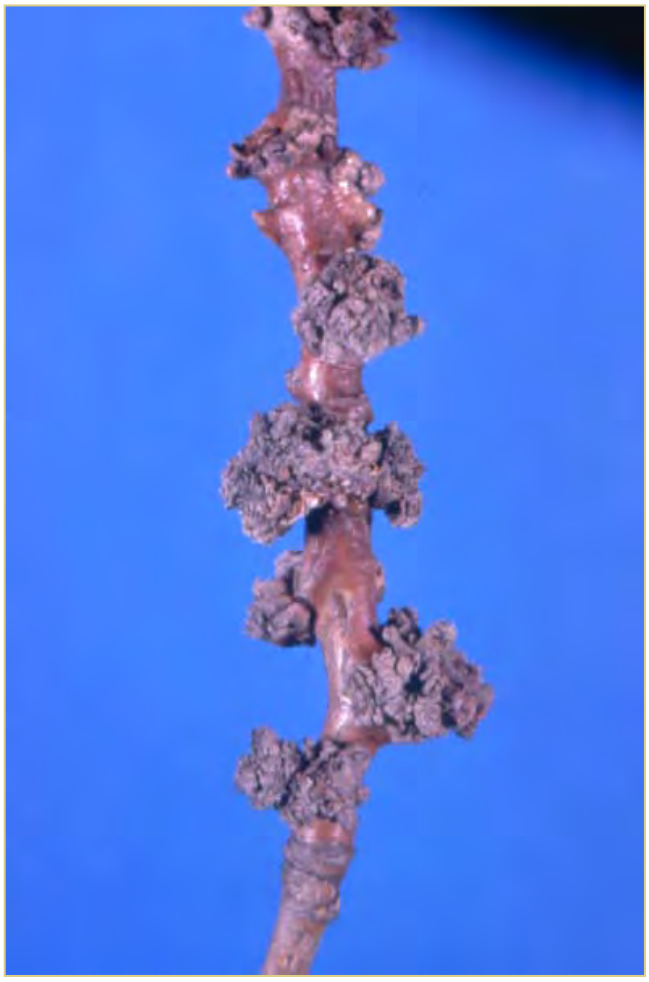
TABLE 2 : TYPES OF DAMAGE

TYPES OF DAMAGE	BORERS	DEFOLIATORS	LEAF MINERS	SAP SUCKERS	GALL FORMERS
Acarina					
Aceria parapopuli				●	●
Hemiptera					
Mordwilkoja vagabunda					●
Parthenolecanium corni				●	
Phleomyzus spp.				●	
Coleoptera					
Altica populi		●			
Anaerea (= Saperda) spp.	●				
Anoplophora spp.	●				
Apriona spp.	●				
Batocera lineolata	●				
Byctiscus populi		●			
Capnodis miliaris	●				
Chrysomela (= Melasoma) spp.		●			
Compsidia (= Saperda) populnea	●				
Cryptorhynchus lapathi	●				
Melanophila picta	●				
Phratora (= Phyllodecta) spp.		●			
Phyllobius spp.		●			
Platypus sulcatus	●				
Polydrusus (= Polydrosus) spp.		●			
Xyleborus (= Anisandrus) dispar	●				
Lepidoptera					
Cerura (= Dicranura) spp.		●			
Choristoneura conflictana		●			
Clostera (= Pygaera) spp.		●			
Cossus cossus	●				
Epinotia solandriana		●			
Gypsonoma spp.	●		●		●
Hyphantria cunea		●			
Leucoma (= Stilpnotia) spp.		●			
Operophtera brumata		●			
Orgyia spp.		●			
Paranthrene tabaniformis	●				●
Phassus (= Endoclita) excrescens	●				
Phyllocnistis spp.			●		
Phyllonorycter (=Lithocolletis) spp.					
Porthetria (= Lymantria) spp.		●			
Sesia (=Aegeria) apiformis	●				
Yponomeuta (=Hyponomeuta) rorrela		●			
Zeuzera pyrina	●				
Hymenoptera					
Janus spp.		●			
Nematus spp.		●			
Trichiocampus spp.		●			
Diptera					
Dasineura (=Rabdophaga) salicis					●
Phytobia (= Dizygomyza) spp.	●				

PHOTOS

Damage of Aceria parapopuli

Damage of Aceria parapopuli



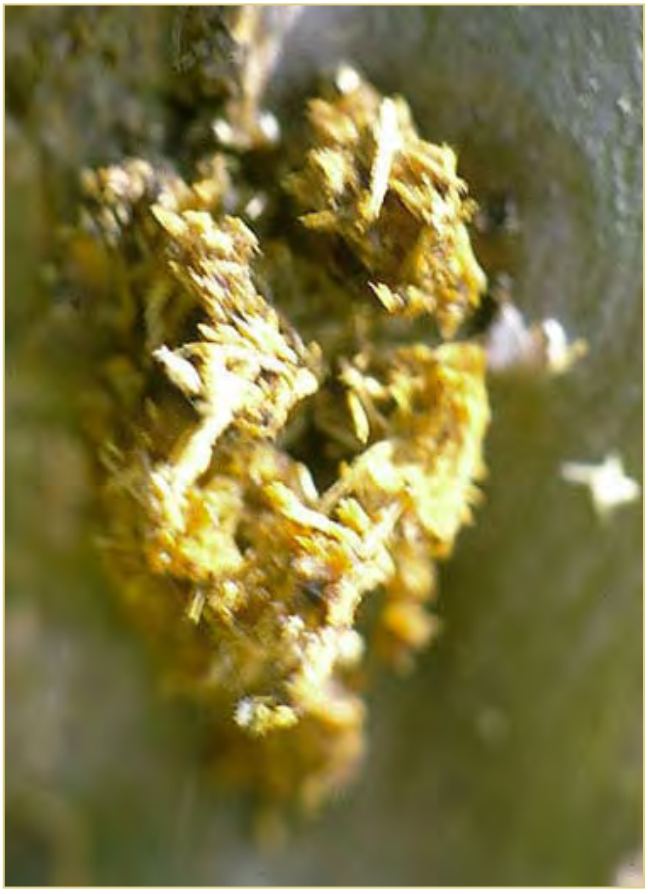
Altica populi adult

Altica populi larvae feeding on leaf

Anaerea carcharias adult on leaf

Anaerea carcharias larva in gallery

Anaerea carcharias pupa in gallery



Anaerea carcharias frass on the trunk

Anaerea carcharias injury in the wood

Anaerea calcarata adult

Anaerea calcarata larva in gallery

Anolophora glabripennis adult female

Anolophora glabripennis larva in gallery

Anoplophora glabripennis pupa in gallery

Anoplophora glabripennis egg niches and sap streak on trunk

Anoplophora glabripennis injury in trunk

Anolophora glabripennis adult

Anolophora horsfieldi adult

Apriona germari larva

Apriona germari adult

Apriona germari pupa

Apriona germari gallery in bark

Batocera lineolata adult

Batocera lineolata adult on a leaf

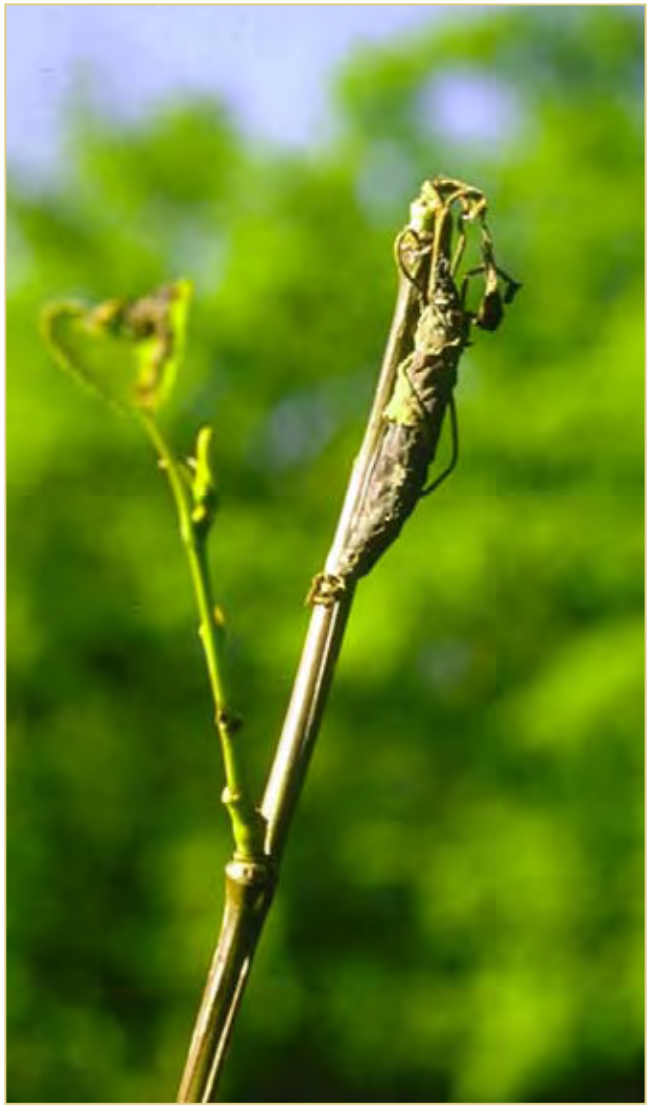
Batocera lineolata adult on bark

Byctiscus populi feeding on leaf

Byctiscus populi on rolled leaf

Byctiscus betulae feeding on leaf

Rolled leaves by Byctiscus betulae



Injury caused by Byctiscus populi on poplar

Capnodis miliaris adult

Cerura vinula adult

Cerura vinula larva feeding on leaf

Cerura vinula cocoon

Choristoneura conflictana adult

Choristoneura conflictana larva

Choristoneura conflictana damage

Chrysomela populi adult

Chrysomela populi eggs

Chrysomela populi larva

Chrysomela populi pupa

Chrysomela spp. adults damage on leaves

Chrysomela tremulae adult

Chrysomela tremulae eggs

Chrysomela tremulae larvae

Chrysomela tremulae pupa

Chrysomela spp. larvae damage on leaves

Chrysomela scripta adult

Chrysomela scripta eggs

Chrysomela scripta young larvae

Chrysomela scripta larva damage

Chrysomela scripta adult damage

Clostera anastomosis adult on a leaf

Clostera anastomosis defoliation

Clostera anastomosis larva

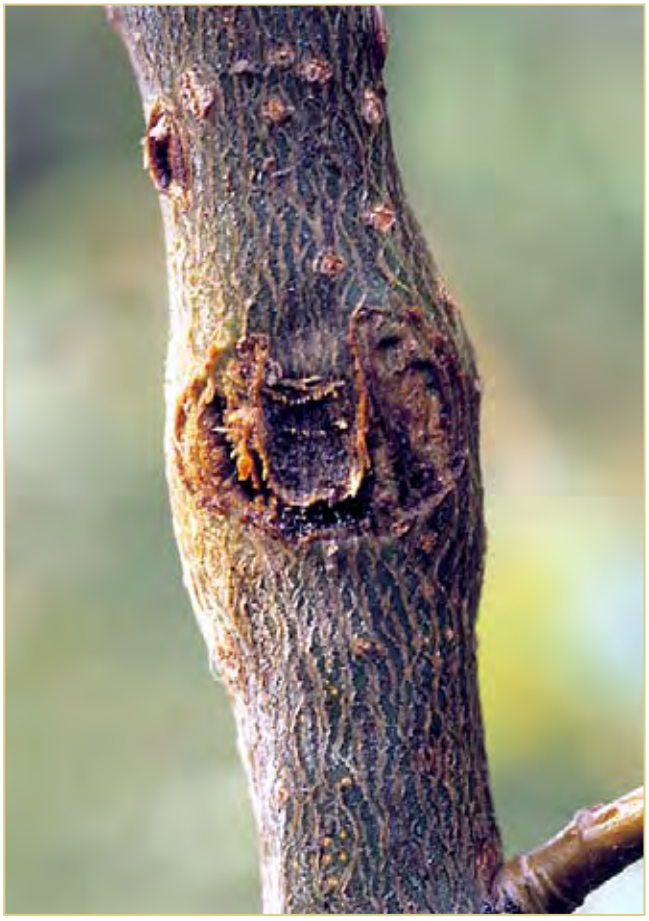
Clostera anachoreta adult on a leaf

Clostera anachoreta larvae on a leaf

Clostera anachoreta defoliation

Compsidia populnea adult

Compsidia populnea egg in horseshoe shaped notche



Compsidia populnea larva in gallery

Compsidia populnea gall on branch

Cossus cossus adult

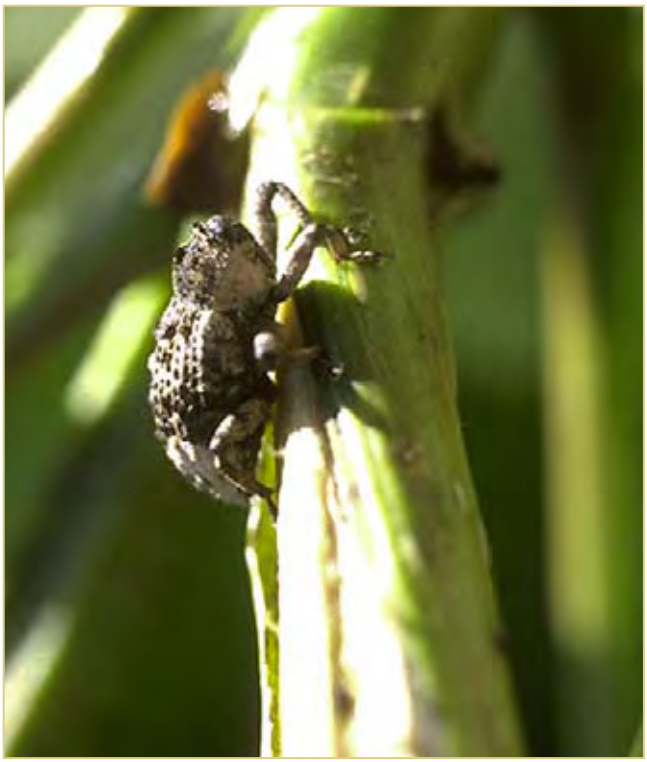
Cossus cossus larva

Cossus cossus pupal exuvia

Cossus cossus chrysalis

Cossus cossus damage at the base of the trunk

Cryptorhynchus lapathi adult



Cryptorhynchus lapathi larva

Cryptorhynchus lapathi damage on young branch

Sap streak from Cryptorhynchus lapathi larvae feeding

Breakdown of poplar trees after Cryptorhynchus lapathi attack

Dasineura salicis gall on willow branch

Epinotia solandriana adults

Epinotia solandriana larva

Epinotia solandriana adult

Epinotia solandriana damage

Gypsonoma aceriana adult

Gypsonoma aceriana young larva frass

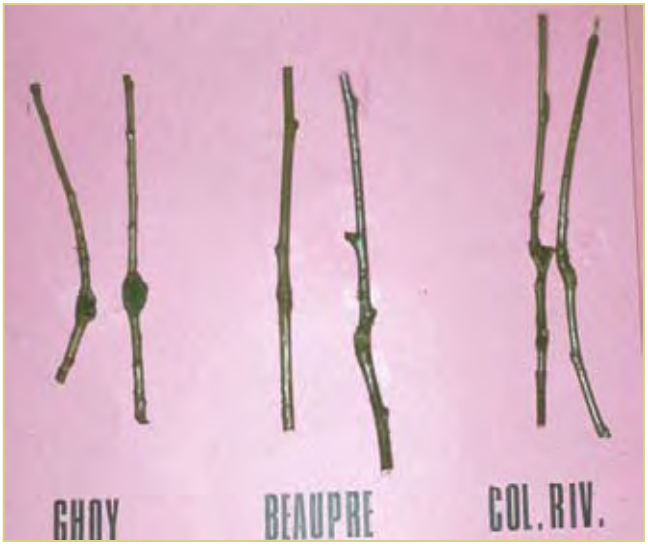
Frass of Gypsonoma aceriana larva on young shoot

Injury of shoots caused by Gypsonoma aceriana

Gypsonoma haimbachiana larva

Reaction of a branch after attack of Gypsonoma aceriana

Gypsonoma haimbachiana galls on different clones



Repeated attacks of Gypsonoma aceriana

Hyphantria cunea adults

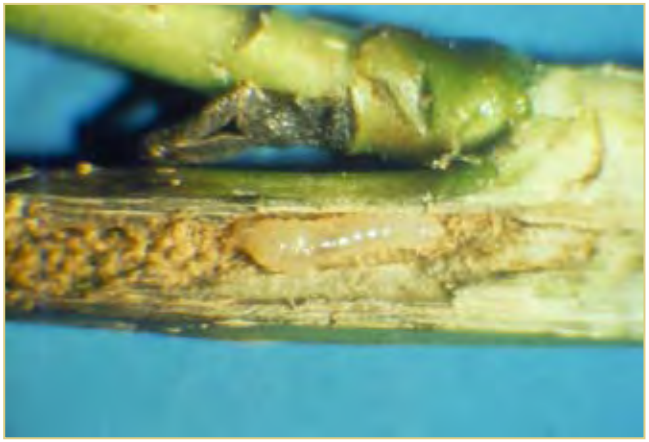
Hyphantria cunea larva

Hyphantria cunea defoliation

Hyphantria cunea damage

Janus abbreviatus larva in gallery

Janus abbreviatus larva in gallery



Janus abbreviatus exit hole

Janus abbreviatus injury to shoot

Leucoma salicis adult

Leucoma salicis cluster of eggs

Leucoma salicis larva

Leucoma salicis chrysalis

Leucoma salicis damage

Leucoma salicis defoliation

Leucoma salicis parasitoid: Telenomus nitidulus

Melanophila picta adult

Melanophila picta larva in gallery

Mordwilkoja vagabundus injury

Nematus oligospilus adult

Nematus oligospilus larva

Nematus oligospilus defoliation on willows

Nematus melanaspis adult

Nematus melanaspis cluster of eggs

Nematus melanaspis larva

Nematus melanaspis larvae

Operophtera brumata adult female

Operophtera brumata adult male

Operophtera brumata larva

Operophtera brumata defolation

Orgyia antiqua adult female

Orgyia antiqua adult male

Orgyia antiqua cluster of eggs

Orgyia antiqua larva

Orgyia thyellina adult female

Orgyia thyellina adult male

Orgyia thyellina cluster of eggs

Orgyia thyellina larva

Paranthrene tabaniformis adult male

Paranthrene tabaniformis adult female

Paranthrene tabaniformis exuvia of chrysalis

Paranthrene tabaniformis larva in gallery

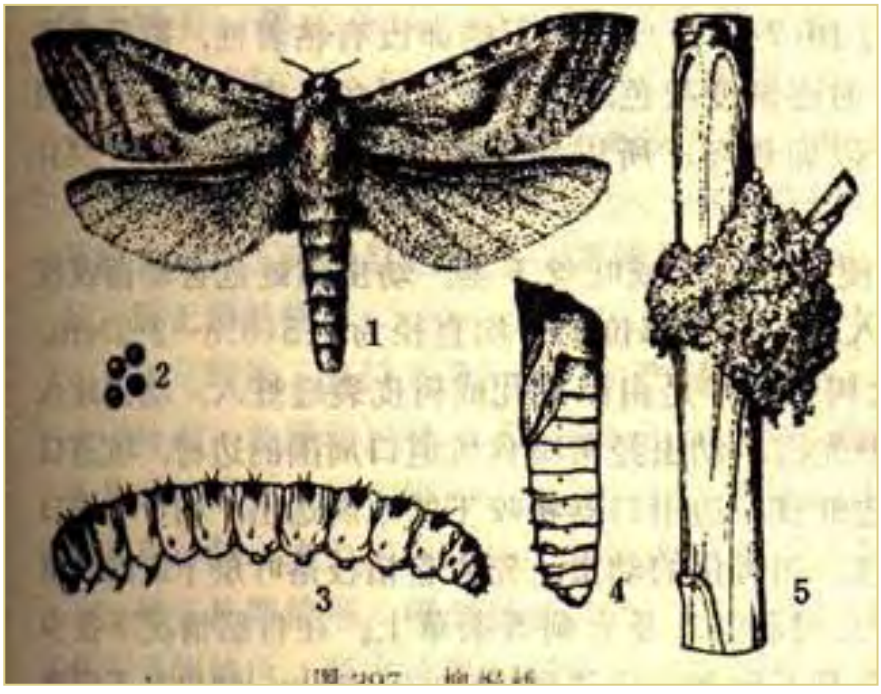
Paranthrene tabaniformis gall

Paranthrene tabaniformis exit hole

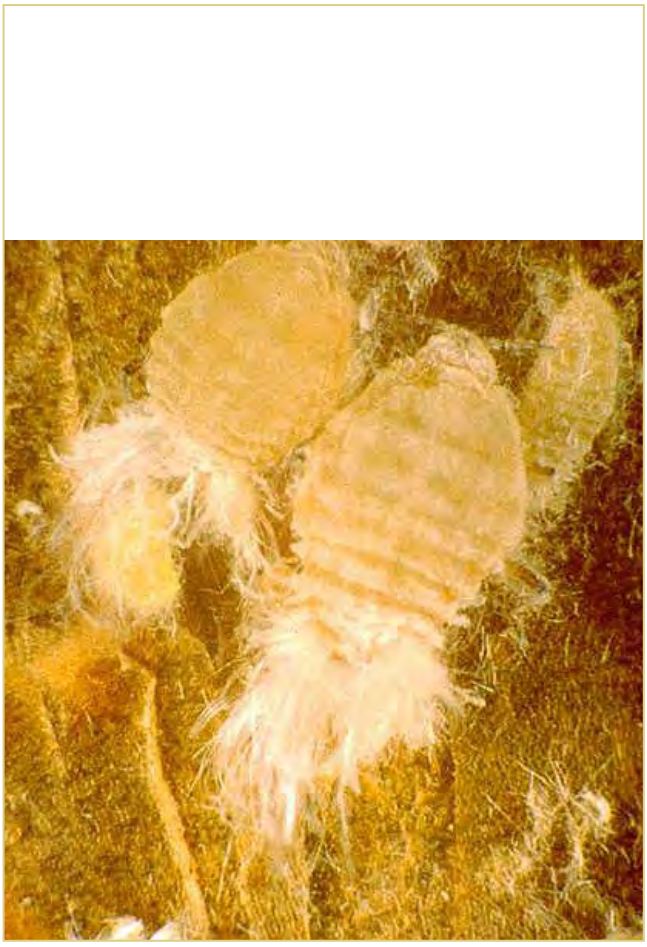
Parthenolecanium corni adults

Phassus excrescens adult

Phassus excrescens stages



Phloeomyzus passerinii adult



Phloeomyzus passerinii injury on the trunk

Phratora vitellinae adult

Phratora vitellinae cluster of eggs

Phratora vitellinae damage

Phratora vitellinae larvae

Phratora vulgatissima eggs and larvae

Phratora vulgatissima overwintering *adult*

Phyllobius oblongus adult

Phyllobius betulae adult

Phyllobius betulae damage

Phyllocnistis unipunctella adult

Phyllocnistis unipunctella larva in mine

Phyllocnistis unipunctella mine

Phyllocnistis unipunctella gallery

Phyllonorycter spp. adult

Phyllonorycter spp.mines

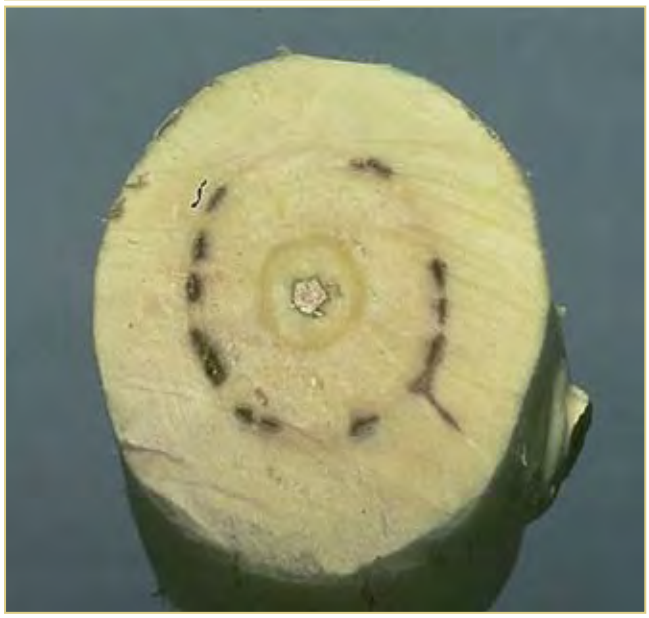
Phyllonorycter spp. damage

Phytobia cambii adult

Phytobia cambii larva

Phytobia cambii pupae

Phytobia cambii injury in wood



Phytobia cambii injury in wood

Platypus sulcatus adult female (left) and male (right)

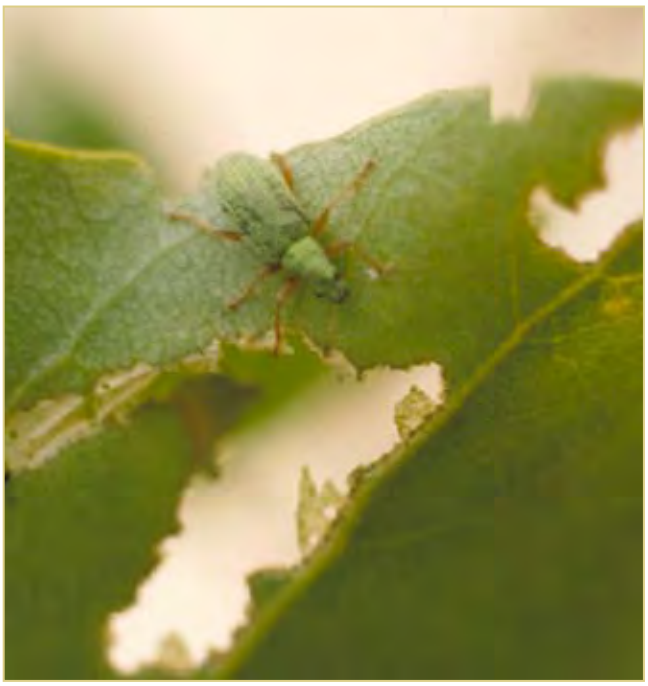
Platypus sulcatus entrance hole

Platypus sulcatus bark injury

Platypus sulcatus injury in plantation

Polydrusus impressifrons adult

Polydrusus impressifrons damage



Porthetria dispar female adult

Porthetria dispar male adult

Porthetria dispar cluster of eggs on the bark

Sesia apiformis eggs

Porthetria dispar larva

Sesia apiformis adults mating

Sesia apiformis larva in gallery

Sesia apiformis chrysalis

Sesia apiformis exit holes at the base of the trunk

Trichiocampus viminalis eggs on petiole

Trichiocampus viminalis larvae

Trichiocampus viminalis damage

Xyleborus dispar adult

Xyleborus dispar adult entrance hole

Xyleborus dispar adult exit hole

Xyleborus dispar damage in wood

Xyleborus dispar damage in wood

Yponomeuta spp. adult

Zeuzera pyrina adult

Zeuzera pyrina chrysalis exuvia

Zeuzera pyrina larva