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GRAPE INSECTS

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The world's vineyards cover 10 million hectares and produce 250 million hectolitres of wine, 70 million hundredweight of table grapes, 9 million hundredweight of dried grapes, and 2.5 million hundredweight of concentrate. Thus, both in terms of quantities produced and the value of its products, the vine constitutes a particularly important cultivation.

THE HOST PLANT AND ITS CULTIVATION

The original area of distribution of the genus *Vitis* was broken up by the separation of the continents; although numerous species developed, *Vitis vinifera* has been cultivated from the beginning for its fruit and wine producing qualities (43, 75, 184). This cultivation commenced in Transcaucasia about 6000 B.C. Subsequent human migration spread its cultivation, at first around the Mediterranean coast; the Roman conquest led to the plant's progressive establishment in Europe, almost to its present extent. Much later, the Western Europeans planted the grape vine wherever cultivation was possible, i.e. throughout the temperate and warm temperate regions of the world: North America, particularly California; South America, North Africa, South Africa, Australia, etc.

Since the commencement of vine cultivation, man has attempted to increase its production, both in terms of quality and quantity, by various means including selection of mutations or hybridization. A wide variety of cultivars have been obtained and then spread by vegetative multiplication (74).

Viticulturists, in wishing to spread the cultivation of the vine, have had to chose among the numerous varieties (clones) those that were best adapted to the soil or climate of each particular region. Moreover, a variety of ecological conditions (e.g. soil and climate) have led the viticulturists to carry out many different cultivation practices. Principally because of pruning the vine has become an extraordinary polymorphic plant. Low pruning results in rootstocks bearing short shoots that are not more than 50–60 cm high (bush, cordon, or fan pruning), whereas the tall vines

(trellised, arbor, trained vines, and vines on trees) can reach a height of several meters. Moreover, modern methods of cultivation, particularly mechanized harvesting, have caused the creation of *wide and tall vines*—rows of widely separated rootstocks (2.5 m or more apart), as planned vegetation.

This polymorphism and the diversity of plantation methods creates ecological conditions which inhibit or favor the action of the animal or vegetable pests of the vine. It is highly probable that the modern procedures of noncultivation (suppression of ploughing and use of herbicides) will soon have an influence on the action of pests.

THE PESTS[1]

Originating from a rather limited region, grapes are now intensively cultivated, sometimes to the extent of being a monoculture. When growing over many tens of thousands of hectares, the vine has attracted diverse pests indigenous to the ecosystems into which it has been introduced (4). These pests have adapted so well to the plant that occasionally biological races infesting the vine have developed from indigeneous species. Less commonly, monophagous insects from other *Vitis* species have been transported on plant samples and have infested *V. vinifera.* This is the case with Phylloxera, an insect whose appearance in Europe considerably disturbed and subsequently modified the cultivation of the vine there.

An important note must also be added on the subject of the adaptation of indigeneous insects during the introduction of the vine into a given country. The ecological niches offered by the biocenosis of the vine has been occupied in each country by different species. For example, the vine chrysomelids (*écrivains*) in Europe are different species from those in North America. It is the same for the so-called grape worms. However, these species quite often belong to the same genus —*Lobesia botrana* in Europe, *Lobesia viteana* in the USA. Consequently, pests of the vine will be considered in relation to the part of the plant attacked (Table 1).

On account of the large number of pests attacking the plant throughout the world, papers that provide an exhaustive list are rare; in fact, the only one available is that by Stellwaag in 1928 (174). However, monographs on vine pests are easily found in each vine-growing country: Spain (48), Italy (23, 168), Algeria (62), Switzerland (41), Romania (121), Moldavia (166, 201), Turkey (80, 88), Azerbaidjan (100), USSR (114), California (170), eastern USA (66, 123), Chile (137), Japan (89), Australia (18, 125, 182), and France (19, 20, 32, 43, 64, 75, 110, 122).

Root Pests

Formerly the most damaging pest of the vine was, without doubt, Phylloxera, *Dactylosphaera* (*Viteus*) *vitifolii,* which in a few years completely destroyed 2,500,000 ha of vine in western Europe. The species was described in 1854 in New York State and subsequently recorded at several sites in the eastern United States.

[1]Only insects and mites are studied here; nematodes are not, even though they cause direct damage to the vine roots and even though certain species of the genus *Xiphinema,* for example, are redoubtable vectors of virus (82, 198).

Table 1 Grape insects

Plant organ attacked	Pest: Order	Region	Ref.
Roots	Homoptera		
	Dactylosphaera (*Viteus*) *vitifolii*	World	12, 33–36, 42, 58, 98, 99, 107, 108, 117, 118, 122, 134, 135, 170, 175–179, 186, 187
	Cicada spp.	S. Europe	174
	Tibicen haematodes	S. Europe	29
	Cicada septemdecim	California	170
	Rhizoecus falcifer	California	170
	Margarodes meridionalis	California	170
	Margarodes vitis	Chili	174
	Margarodes capensis	S. Africa	174
	Margarodes greeni	S. Africa	174
	Eurhizoecus brasiliensis	Brasil	72
	Coleoptera		
	Bromius obscurus	Europe, N. America	19
	Fidia viticida	N. America	66
	Scelodonta strigicollis	India	109
	Vesperus spp.	France, Spain, Italy	63, 146
	Pentodon spp.	S. Europe	19, 32, 122
	Phyllognatus excavatus	S. Europe	85
	Opatrum sabulosum	Europe	32
	Lepidoptera		
	Vitacea polistiformis	Missouri	59, 155
Wood			
Trunk	T. Isoptera		
	Calotermes flavicollis	S. Europe	71
	Reticulitermes lucifugus	S. Europe	71
	Reticulitermes hesperus	California	170
	Lepidoptera		
	Cossus cossus	S. Europe	70
	Paropta paradoxus	Israel, Egypt	141
	Coleoptera		
	Anaglyptus mysticus	Bulgaria	163
Shoots	S. Homoplera		
	Eulecanium corni	S. Europe	20, 32
	Pulvinaria vitis	S. Europe	20, 32
	Diaspidiotus uvae	California	170
	Divers		
	Ceresa bubalus (Membracidae)	E. United States	143, 168, 192
	Bostrychidae	S. Europe	122, 129
	Macrophya strigosa (Tenthredinidae)	S. Europe	122
	Polycaon confertus (Coleoptera)		170
Buds and very young shoots	Lepidoptera		
	Arctia caja	S. Europe	19, 20, 27, 32
	Noctuidae	World	19, 20, 26, 32, 53, 151, 170
	Coleoptera		
	Peritelus sphaeroides	S. Europe	19, 32, 84
	Peritelus noxius	S. Europe	19, 32, 84

Table 1 *(Continued)*

Plant organ attacked	Pest		Ref.
	Order	Region	
	Limonius canus	California	170
	Glyptoscelis squamulata	California	170
	Pocalta ursina	California	170
	Phlyctinus callosus	S. Africa	24, 25
	Eremnus cerealis	S. Africa	24, 25
	Eremnus stulosus	S. Africa	24, 25
	Acarina		
	Calepitrimerus vitis	S. Europe	120, 148
	Eriophyes oculivitis	Egypt	11
	Eriophyes vitineusgemma	Moldavia	119
Leaf	Lepidoptera		
	Sparganothis pilleriana	S. Europe	142, 145, 149, 169
	Celerio lineata	Europe, N. America	19, 20, 32, 170
	Pholus achemon	California	170
	Antispila rivillei	Georgia	57
	Harrisina brillans	Mexico, California	84a, 123, 140, 170
	Sylepta lunalis	India	136
	Coleoptera		
	Haltica lythri subsp. *ampelophaga*	Europe	122
	Haltica chalybea	California	170
	Haltica torquata	California	170
	Bycticus betulae	Europe	19
	Desmia funeralis	N. America	5, 69, 93
	Homoptera		
	Aphis illinoisensis	E. United States	123
	Cicadoidea		
	Philaenus spumarius	N. America, Europe	83, 144, 170, 200
	Scaphoideus littoralis	N. America, France, Germany, Switzerland, Italy	45, 50, 51, 76, 79
	Empoasca flavescens	Europe	13, 14, 30, 31, 52, 57, 128, 131, 160, 162, 189, 190, 193
	Empoasca lybica	Spain, S. Italy, Maghreb, Tanganyka	191
	Flata ferrugata	Punjab	171
	Unnata intracta	Punjab	171
	Zygina rhamni	France	
	Erythroneura adanae vitisuga	Bulgaria	102
	Erythroneura comes	California	96, 170, 173
	Erythroneura variabilis	California	96, 170, 173
	Erythroneura elegantulae	California	96, 170, 173
	Erythroneura ziczac	British Columbia	124
	Heteroptera		
	Nyzius senecionis	France	
	Nyzius ericae	Europe, America	22
	Acarina		
	Eotetranychus carpini	S. Europe	65, 81
	Panonychus ulmi	S. Europe	47
	Brevipalpus lewisi	Bulgaria	21

Table 1 *(Continued)*

Plant organ attacked	Pest		Ref.
	Order	Region	
	Tetranychus pacificus	California	104, 105, 111, 173
	Tetranychus flavus	California	170, 173
	Tetranychus atlanticus	France	
	Oligonychus mangiferae	India	167
Gall makers	Acarina		
	Eriophyes vitis	S. Europe	77, 126, 148
	Eriophyes vitigenusgemma	Moldavia	119
	Eriophyes oculivitis	Egypt	11, 202
	Homoptera		
	Dactylosphaera (Viteus) vitifolii	World	179, 180
	Diptera		
	Janetiella oenophila	France, Italy	129
	Lasioptera vitis	E. United States	66
	Dasyneura vitis	E. United States	66
	Schizomyia pomorum	E. United States	66
Fruits	Lepidoptera		
	Eupoecila ambiguella	Europe	3, 4, 17, 44, 56, 73
	Lobesia botrana	Europe	78, 91, 92, 96, 101, 112, 133, 145, 153, 165, 175, 183, 188, 197
	Lobesia viteana	E. United States	18, 66, 87, 181, 185
	Argyrotaenia politana	France	32
	Argyrotaenia velutinana	E. United States	95, 185
	Platynota stultana	California	7, 8, 115, 173
	Phalaenoides glycine	Australia	18
	Epiphyas postvittana	Australia	18
	Serrodes partitus	S. Africa	132, 199
	Coleoptera		
	Craponius inaequalis	E. United States	123
	Lopus sulcatus	France, Italy	32
	Heteroptera		
	Euchistus conspersus	California	170
	Chalcidoidea		
	Prodecatoma cooki	Florida	2, 55, 164
	Cecidomyidae		
	Contarinia viticola	France	122
	Thysanoptera		
	Drepanothrips reuteri	N. America, S. Europe	15, 16, 38–40, 139
	Anaphothrips vitis	Bulgaria, Romania, Greece, Turkey	203
	Haplothrips globiceps	Turkey	54
	Retithrips aegyptiacus	N. Africa, Middle East	152
	Rhipiphorothrips cruentatus	India	10
	Scirtothrips dorsalis	Japan	89
	Heliothrips haemorrhoidalis	World	
	Scirtothrips citri	California	170
Honeydew producers	Homoptera		
	Planococcus citri	S. Europe	6, 60
	Planococcus maritimus	California	6, 60
	Planococcus ficus	France	138

Table 1 *(Continued)*

Plant organ attacked	Pest		Ref.
	Order	Region	
	Eulecanium corni	S. Europe	20, 32
	Eulecanium persicae	S. Europe	20, 32
	Pulvinaria vitis	S. Europe	20, 32
	Pulvinaria betulae	Romania	127
	Trialeurodes vittatus	California	170
Aerial polyphagous insects	Orthoptera		
	Barbitistes fischeri v. *berenguieri*	France, Spain, Italy	122
	Ephippiger spp.	S. Europe	122
	Miogryllus convolutus	S. America	113
	Locusta migratoria	S. Europe, N. Africa	122
	Schistocerca peregrina	S. Europe, N. Africa	122
	Dociostaurus maroccanus	S. France	
	Coleoptera		
	Macrodactylus subspinosus	E. United States	
	Popilia japonica	California	123
	Anomala spp.	France	85
	Hymenoptera		
	Vespidae	World	156, 195
Polyphagous soil insects	*Melolontha melolontha*	Europe	85, 121
	Polyphylla fullo	Europe	85, 121
	Anoxia villosa	Europe	85, 121
	Otiorrhynchus sulcatus	Bulgaria	86
	Otiorrhynchus turca	Bulgaria	86
	Agriotes obscurus	Romania	90

One of the areas of penetration into Europe occurred in France in the Gard region (in 1863), where the insect was introduced on some American vinestocks. Westwood recorded it in England in 1867. Little by little the pest spread throughout Europe (186) and then, despite precautions, throughout the whole world. At present, regions that are still untouched are rare. The biology of this species has been studied in each country where it has been introduced. In some places the full cycle of both aboveground and underground stages have been observed, in others only the underground stage is constant. Sometimes rare swarms of winged forms unable to reproduce are found (108, 117, 118, 170, 176). These variations in the insect's life cycle are usually explained by ecological conditions, temperature, and humidity (108, 117, 118). Some have thought also that the isolation of diverse populations of the underground stage and their adaptation to the biotope has permitted the creation of races with particular morphologies or biologies (33, 118, 135). For example, on *Vitis vinifera,* the radicicoles produce enormous tuberosities on the roots, thereby causing the death of the rootstock. On American vines they cause only very slight damage because they produce only shallow wounds and because many of them swarm before winter. The origin of this resistance has been the subject of many studies (34–36, 58, 107, 134) because it is the basis for the control of Phylloxera.

The cultivars of *Vitis vinifera* are therefore grafted onto American *Vitis* stocks. Attempts have also been made to hybridize them to avoid grafting, which is a burdensome operation which causes a delay in production. But these resistant directly-producing hybrids, if allowed to spread again to the area of vine cultivation, give a disagreeable taste to the wine. Planting these hybrids has been prohibited in France. Another method of control for radicicole Phylloxera consists of injecting carbon disulfide (CS_2) into the soil, but this method is very costly and can only be applied over small areas and in vineyards yielding high returns (42). Other methods of chemical control have been recommended for the gall-making stages (12, 42, 98, 177, 179), as well as for the root-feeding stages (98, 99, 175, 178, 187). Note that the radicicoles may also be destroyed by flooding and submersion of the vines for 50 days.

Among the other root-sucking insects one should mention the cicadas, *Cicada plebeja, C. orni, C. atra* (174), and *Tibicen haematodes* in Europe, (29) and *C. septemdecim* in California (170). The larvae, which live for several years in the soil, pierce the cortical parenchyma and suck the exudate.

Certain coccids are also found on vine roots. The ground mealybug *Rhizoecus falcifer* in California is seldom damaging (170). On the other hand in *Margarodes meridionalis* in California (170), *Eurhizococcus brasiliensis* in Brazil (72), *M. vitis* Chile, and *M. capensis* and *M. greeni* in South Africa (174), the globular females fix themselves on the rootlets and thus weaken the stocks.

Coleopterous larvae, which have a subterranean life, cause damage by gnawing the roots. In Europe *Bromius obscurus,* which was previously a pest of some importance, has now become quite rare. The larvae destroy the cortical part and the superficial wood of the roots (19). They live with difficulty on the roots of American *Vitis,* which explains their rarity after the widespread use of American rootstocks following the crisis caused by Phylloxera. The adult bites and pierces the parenchyma of the leaves and the epidermis of the young grapes following a sinuous line, hence the name *writer* (*écrivain*) which has been given to it. The species is parthenogenetic and only the female is known. It has been introduced into North America, where another species, the grape rootworm beetle, *Fidia viticida,* causes similar damage (66). In India a third Eumolpine, *Scelodonta strigicollis,* behaves in the same way as the two above-named species. The wounding caused by the larvae on the roots often leads to the death of the rootstock. The adult gnaws the surface of the young leaves of the vine shoots and the young grapes (109).

Other oligophagous Coleoptera larvae are also injurious to the roots of the vine. Around the Mediterranean the genus *Vesperus,* with *V. xatarti, V. strepens,* and *V. luridus,* causes local but often serious damage (63, 146); in addition, *Pentodon punctatus, P. idiota, P. bispinosus* (19, 32, 122), *Phyllognathus excavatus* (85), and a Tenebrionidae, *Opatrum sabulosum* (32), have larvae which attack the collar of the young rootstocks and gnaw the graft calluses.

The caterpillar of *Vitacea polistiformis* also causes considerable damage to roots in the Missouri region, where certain vineyards have been completely destroyed (59). Their life cycle lasts three years. The first-instar larvae have very poor resistance to drought (155).

Wood-Damaging Pests

ON THE TRUNK Termites attack rootstocks that are in poor condition for any of several reasons such as lesions caused by frosting, by agricultural implements or poor circulation of the sap, due, for example, to an incorrect choice of a graft stock that is ill-adapted to the soil. Examples in France are the yellownecked termite *Calotermes flavicollis* and, more rarely, *Reticulitermes lucifugus* (71), and in California *Reticulitermes hesperus* (170).

Cossus cossus (70), whose large, red caterpillar sometimes destroys the rootstock in Europe, has its homolog in *Paropta paradoxus* (141) in Israel and in Egypt. Finally, in Bulgaria a cerambycidae, *Anaglyptus mysticus,* has recently been observed (163). The larvae destroy the cambial tissue, causing the death of 13% to 15% of the rootstock of four- to seven-year-old vines.

The control of trunk-attacking species is difficult. For the termites and *Cossus,* the only method of control is to maintain the vine in excellent condition. On the other hand, it seems that oleoparathion preparations or dichlorvos are effective for controlling *A. mysticus* (163).

ON THE SHOOTS *Scale insects* In Europe and America, two Diaspidae, *Eulecanium corni* and *Pulvinaria vitis,* attack the shoots, as does the grape scale *Diaspidiotus uvae* in California (170). They are damaging not only because they remove the sap, but also because of the toxicity of their saliva. Other species of Coccidae [*Planococcus citri* (20, 32) and *Planococcus ficus* (138) in Europe and *Planococcus maritimus* in America (170)] cause a similar nuisance, but they are mobile and damage principally the young grapes because of the coccids production of honeydew and the subsequent growth of the sooty mould fungi on the honeydew.

Others Other insects attack the vine shoots but the damage inflicted is never very important, as in the following examples:

1. Cicadas make fusiform egg-laying cicatrices.
2. *Ceresa bubalus* has rings of egg-laying punctures around the shoot which destroy the vascular system and produce a spectacular callus above the wound (168, 192). This species passes part of its life cycle on fruit trees and the vine and then part on herbaceous cultivated or adventitious plants. An attempt at biological control using the egg parasite *Polynema striaticorne* is underway (143).
3. The Bostrychids—*Apate sexdentatum* (129), *Apate muricata, Schistoceros bimaculatus*—attack decaying stocks and penetrate at bud level to lay eggs there. The larvae bore longitunal galleries in the pith (122).
4. The branch and twig borer *Polycaon confertus* is found in California. The adult feeds by chewing a hole in the base of the young shoots, which then may be broken by the wind. The larva lives in the main branches of the stock in decaying or dead wood (170).
5. The vine sawfly, *Macrophya strigosa,* lays its eggs in the green shoots; the larva descends into the pith and bores its gallery until it reaches the buds. The damage can be locally important (122).
6. Finally, numerous Hymenoptera species make notches in the pith to nest there.

Bud Pests

The damage caused by these insects always has a catastrophic effect on the crop. In Europe, the tiger moth, *Arctia caja,* or *chenille bourrue,* so named because of its hairiness, overwinters as a caterpillar on weeds and afterwards passes onto the vine devouring five to six buds a day at the time of bud break and later on attacks the young shoots and the floral buds. A method of chemical control has been perfected (27); in addition, an entomogenous fungus, *Entomophtora sphoeroderme,* produces fierce and deadly epidemics among the caterpillar populations.

Throughout the world numerous species of noctuids (cutworms) are known as bud destroyers. In Europe the most important pests are *Autographa gamma, Agrotis segetum, Euxoa nigricans, Triphaena pronuba,* etc (53). In America some of the most prominent pests are the variegated cutworm *Peridromia margaritosa,* the Greasy cutworm *Agrotis ipsilon* (170), and the cutworms, *Anagrotis barnesis* (134) and *Rhynchagrotis cupida* (151). The caterpillars of all these species pass the day a few centimeters below the soil at the foot of the rootstocks; they come out at night to feed on the buds. Although the viticulturist was for a long time defenseless against them, they can now be effectively controlled (26, 53).

Some Coleoptera in the adult stage may also attack buds, e.g. in Europe the vine grubs (*coupe bourgeons*), *Peritelus sphaeroides* and *P. noxius* (84), and in America the diurnal click beetle *Limonius canus,* the grape bud beetle, *Glyptoscelis squamulata,* whose adults penetrate into the buds without damaging the scales, and the little bear beetle, *Pocalta ursina,* which does only occasional damage (170). In South Africa three species of vine grub are found: *Phlyctinus callosus, Eremnus cerealis,* and *E. stulosus* (24, 25).

Finally, one must mention the mite, *Calepitrimerus vitis,* which hinders the development of the buds and young shoots by the damage caused by infestations. The internodes are short and sometimes the grapes abort (120, 148). *Eriophyes oculivitis* (11) in Egypt and *E. vitineusgemma* (119) in Moldavia have recently been described, and their damage is similar to that of the preceding species. Some tydeids are effective predators of these phytophages (157, 159, 202).

Leaf Pests

LEPIDOPTERA The pyralid *Sparganothis pilleriana,* once common throughout all French vineyards, appears to have declined sharply (169). It has only one generation per year, and the first-instar caterpillar, which hibernates in a cocoon under the bark of the vinestock, can be destroyed at that moment by sprayings of sodium arsenite. Use of this chemical is currently allowed, but it is being replaced by phosphoric acid esters (145). At the three-to-four-leaf stage the larvae are killed by toxaphene, which is also active against the hairy caterpillar (*chenille bourrue*) (149). Numerous indigenous parasites control the populations of the pyralid. The caterpillars have a marked preference for the plants whose leaves are rich in protein (142). Among the sphingid caterpillars, the whitelined sphinx moth, *Celerio lineata,* is the most damaging in France as well as in California. In the latter region, the achemon sphinx moth, *Pholus achemon,* is also found (170). The larvae of *Antispila rivillei* have been recorded as vine leafminers in Georgia (57).

Another Lepidoptera, the western grapeleaf skeletonizer, *Harrisina brillans,* which has passed from Mexico into California, has curious, gregarious caterpillars with black-and-red-striped, yellow bodies. The larvae destroy the leaf blade without damaging the upper epidermis (140, 170). There have been attempts at microbiological control (123) and biological control (84a). In India the caterpillars of *Sylepta lunalis* destroy just as completely the parenchyma of the leaves which they roll (136).

COLEOPTERA The halticids, *Haltica lythri* ssp. *ampelophaga* in Europe and *Haltica chalybea* and the grape flea beetle *Haltica torquata* (170) in California, have gregarious larvae which also eat the leaf blade without damaging the cuticle.

The leafrollers *(cigariers), Byctiscus betulae,* in France and the grape leaffolder, *Desmia funeralis,* in America have females which cut the leaves and roll them into "cigars" within which they lay their eggs and which serve as food for the larvae. Treatment trials against this last species have shown that a preparation based on *Bacillus thuringiensis* is as effective as some chemical pesticides (carbaryl) (5, 93). Attempts at biological control by the rearing and release of natural parasites have given encouraging results (69).

HEMIPTERA Only one species of aphid has been recorded on the vine, *Aphis illinoisensis.* It produces heavy infestations on young shoots and on the leaves in summer to the east of the Mississippi River. It is dioecious and migrates in autumn onto its principal host (123).

On the other hand, a number of cicadellid species are vectors of phytopathogenic agents. Pierce's disease, found in North America, has 20 species as vectors (83, 144, 170, 200). One of the most efficient among these is *Philaenus spumarius,* a cercopid, which also occurs in France where very fortunately Pierce's disease is not found. The golden yellows, a disease which appeared about 1950 in the southwest of France, is also caused by a molicute (79). The vector is *Scaphoideus littoralis,* a species of American origin. The disease has spread and at present affects Switzerland, Italy, Sardinia, Corsica, and perhaps Germany (45, 50, 51, 76). Furthermore, the disease of black wood (*bois noir*), which is rife in Burgundy and in the Jura, very probably has a cicadellid as vector also (49, 194).

The cicadellids can also cause direct damage by piercing the phloem into which their toxic saliva is injected (30, 31, 160, 162, 189, 190), e.g. *Empoasca flavescens,* which has multiplied in France during the last few years, perhaps because of the physiological condition of the vine after pesticide treatment (57). It causes a crinkling of the leaf, a hardening of the leaf blade, and a browning of the nerves (14). The leaves dry up from the periphery towards the center and then fall (131, 193). Quite often the treatment against the grape moths *(tordeuses)* is sufficient to control *Empoasca vitis* (= *E. flavescens)* (13, 52, 128). *Empoasca libyca* (191) causes the same damage in hotter regions, such as southern Spain, Sicily, Sardinia, North Africa, Israel, and Tanganyika. *E. decipiens,* though not a pest in France, is one in Baluchistan. Recently, two Flatidae, *Flata ferrugata* and *Unnata intracta,* have infested the vine in the Punjab (171). Finally, other species—*Zygina rhamni* in

France, *Erythroneura adanae vitisuga* in Bulgaria (102), *E. comes, E. variabilis,* and the grape leafhopper, *E. elegantulae,* in California (96, 173), and *E. ziczac* in British Columbia (124)—are also damaging to the vine. *Ceresa bubalus,* already mentioned for the damage it does on the shoots, also causes a crinkling and a reddening of the leaves.

Other Hemiptera also damage the leaves, such as *Nyzius senecionis,* which pierces at bud level and whose toxic saliva produces the drying-up of what is above the wound. The false chinch buy *Nysius ericae* lives in Europe and America where it causes damage similar to that of the above-named species (22). These insects migrate by walking from their plant host to the vine. They can thus be controlled by creating a barrier consisting of a ten-meter band of land powdered with lindane.

ACARINES The punctures of the cell feeders gravely damage the leaves, which dry up and fall. The cell feeders in Europe consist of two Tetranychidae: the yellow spider mite, *Eotetranychus carpini,* which lives on the underneath side of the leaves and whose punctures cause red or yellow stains, according to the vine cultivar, along the nerves (65, 81), and the red spider mite, *Panonychus ulmi,* which lives on both sides of the leaves, causing them to take on a grayish tint (47). Recently, heavy infestations of *Tetranychus atlanticus* have appeared in the vineyards of Mediterranean Languedoc, as a consequence of using herbicides (A. Rambier, 1975, personal communication). Other, less-damaging species exist on the vine in France and throughout Europe (21, 126). In California *Tetranychus pacificus* is the homolog of the French tetranychids on the vine (104, 105, 111, 173), and *Tetranychus flavus* dries up the buds and the young, unopened leaves. Their most effective predator is *Metaseiulus occidentalis* (9, 104, 105). *Oligonychus mangiferae* has recently been observed in India, where it produces damage similar to that from the tetranychids on the French vines (167). The mite problem did not exist before the application of synthetic insecticides against the grape moths (*tordeuses*). Many authors have tried to determine the causes inducing these multiplications (45, 56, 158, 173). They are multiple, principally including the selection of resistant races, the suppression of predators (typhlodromids, anthocorids, thrips, etc) (37, 65, 147, 157), and the effects of insecticides on the physiology of the vine and on the mites are in a sense favorable to the fecundity and longevity of the latter (56). Because many synthetic insecticides induce heavy mite infestations, the control of other insects damaging to the vine is often rendered more difficult (3, 17, 73).

GALLMAKERS Leaf blister is caused by the mite *Eriophyes vitis.* The gall occurs as a depression on the underneath part of the leaf. It is lined with white hairs, within which are found the minute mites (77, 126, 148). *E. vitigenus gemma* and *E. oculivitis,* both recently described [the first is from Moldavia (119), the second from Egypt (11, 202)], do not form a blister but instead dry up the buds.

Some other species can also be gallmakers. By its punctures the gall-living form of Phylloxera provokes the formation of galls on American vines and on certain Franco-American hybrids. The gallforming female lives in a globular gall, which opens onto the upper surface of the leaf. Only the young larvae can leave by passing

through the hairs that obstruct the orifice. The sensitivity of different vine cultivars to attack by the gallforming aphids has been tested (180), and diverse insecticides have tried as controls against them (179).

The leaf cecidomyid *Janetiella oenophila* forms lenticular galls between the two cuticles of the leaf (129). One can mention also in America the grapevine tomato gallmakers, *Lasioptera vitis* and *Dasyneura vitis,* as well as another Diptera, *Schizomyia pomorum* (66).

Fruit Pests

The grape moths *(tordeuse de la grappe)* give the most trouble to French viticulturists. The grape tortrix *Lobesia botrana* and the grape tineid *Eupoecilia ambiguella* are often confused by the experts because they have fairly similar biologies and synchronous flight periods, and they cause nearly the same damage. In France *L. botrana* has three annual generations and lives principally in dry situations, whereas *E. ambiguella* has only two generations and lives in humid situations. Their biology (44, 92, 112, 133, 165) and methods of control have been the object of many studies in all countries (3, 4, 68, 91, 97, 101, 112, 145, 153). The treatments used are of two types: preventive, by applications before hatching of the eggs, or curative, by using control measures against the young caterpillars. The treatments are applied after announcements are broadcasted by the Plant Protection Service. In effect, the biology of the two species depends directly on meteorological conditions (175), and it is necessary to have recourse to trapping to determine with precision the date and importance of the flight of adult moths. The captures from food traps are often difficult to identify (183, 197), and confusions with non-pest species can occur (96). The latter can be avoided by the use of sexual traps, which moreover have a high efficiency (78, 188). Observation of egg laying in the vines is being used more and more to fix with certainty the necessity and date of treatment. The damage by the second and especially that done by the third generation of *Eupoecilia* is often severe. The caterpillars penetrate into the grapes, and the entry holes favor the establishment of the fungus of the gray mold *Botrytis cinerea* (3). It is noteworthy that the treatments against the grape moths, in particular those with phosphoric esters, have induced heavy infestations of mites in the vineyards (3, 17, 56, 73).

In the eastern United States, the grape berry moth, *Lobesia viteana,* has the same biology and causes the same damage as the French *Eudemis,* but because pupation occurs not under the bark of the vine stock but instead in a rolled-up leaf on the ground, efficient control by cultural means (66, 87, 181) and by using *Bacillus thuringiensis* (28) is possible. A confusion operation with the aid of sex pheromones has also given good results (185).

The small grape moth *Argyrotaenia politana* was discovered for the first time in Montpellier, France, in 1954. It is questionable whether it is a species newly adapted to the vine, coming from the numerous apple orchards planted a few years before in the region, or whether it has been confused with *Eudemis,* which the adult closely resembles. The damage inflicted by the two species is the same, only the treatment dates differ (32). In the eastern half of the United States, a related species, the redbanded leafroller, *Argyrotaenia velutinana* occurs (95, 185). In California

Platynota stultana (7, 8) has become an important pest during the last few years (115, 173); all of the nonligneous parts are attacked, but the greatest damage is to the grapes. The numerous wounds inflicted on the epidermis permit fungal spores to penetrate and cause rot. Crop losses can reach 15%. In Australia the vine moth, *Phalaenoides glycine,* and the light brown apple moth, *Epiphyes postvittana,* cause the same damage and are justifiably controlled by the same methods as the above-named species (18). A Coleoptera, the grape curculionid *Craponius inaequalis* lays its eggs in the grapes, where the larvae consume the seeds and the pulp (123). In California the consperse stink bug, *Euchistus conspersus,* which habitually lives on low plants, pierces the grapes and thereby greatly depreciates the crop of table grapes (170). A chalcid in Florida, *Prodecatoma cooki,* whose larva lives in the pulp and the seeds (2, 55, 164) and the fruit-piercing moth, *Serrodes partitus* (F.), in South Africa must also be noted (132, 199). Finally, two species whose very infrequent damage can be considered as negligible in France must be mentioned: the polyphagous capsid *Lopus sulcatus,* which sometimes passes onto the vine (32) and whose larvae and adults pierce the flower buds that blacken and fall, and the vine cecidomyid *Contarinia viticola,* cause similar damage (122).

Many species of thrips (Thysanoptera) attack the vine in the world. They are very rarely mentioned because on account of their small size they pass unnoticed and their damage is attributed to other pests. The grape thrips, *Drepanothrips reuteri,* probably originated from California where its biology and control have been studied (15). Introduced into Europe, it had been recorded as damaging solely American vines (139). During the last ten years it has been recorded as damaging hybrid vines first of all (38), then French vines (16, 39, 40). Over and above the damage it causes to the leaves (necrosis or holes in the blade), the punctures of the larvae and of the adults produce a toxic reaction which retards the development of the shoots and causes a certain amount of abortion at the flowering period. The most severe damage is recorded on the grapes where it causes necrosis and suberization of the epidermis; this considerably decreases the varieties of table grape. Its biology and methods of control have been studied in Europe (16, 38–40). The treatments against the second generation of the grape moths are also valuable against thrips. Some vicariant species in other climates occupy the same ecological niche as this species and cause similar damage to the grapes. These include, for instance, *Anaphothrips vitis* (203) in Bulgaria, Romania, and Greece; *Haplothrips globiceps* (54) in Turkey; *Retithrips aegyptiacus* in the Middle East (152), Egypt, and North Africa; *Rhipiphorothrips cruentatus* (10) in India; *Scirtothrips dorsalis* in Japan (89); and *Heliothrips haemorrhoidalis,* a polyphagous species of warm and warm temperate climates which also passes onto the vine in Chile, for example. Other species can also occasionally attack the vine: *Scirtothrips citri* (170) close to citrus orchards and *Hercothrips fasciatus,* as well as the grass thrips *Frankliniella moultoni, F. occidentalis,* and *F. minuta* in the United States.

Honeydew Producers

Certain insects are also a nuisance indirectly because of the production of a sweet honeydew. This secretion serves as a substrate for a black fungal growth, the sooty mould, which greatly depreciates the quality of table grapes.

Among the coccids, the females of *Planococcus citri,* mobile in all stages, have soft integument covered with a white bloom. The species can be effectively controlled by releases of a coccinellid, *Cryptolaemus montrouzieri* (13). *Pseudococcus maritimus* (6, 60) is the California homolog of the above species. One can also mention *Pulvinaria vitis, Eulecanium corni,* and *Eulecanium persicae,* which are controlled successfully by the entomogenous fungus *Beauveria bassiana,* and *Pulvinaria betulae* in Romania (127). These species are quite often controlled by the treatments against the grape moths. Furthermore, since 1969, perhaps because of the employment of organophosphorus insecticides, a new species that is locally very damaging has multiplied throughout the Mediterranean basin: *Planococcus ficus* (138). In California the aleurodid *Trialeurodes vittatus* also produces honeydew.

Polyphagous Aerial Insects

These are principally the Orthoptera. Among the Ensifera, the *Boudrague, Barbitistes fischeri* var. *berenguieri* (122) and three species of the genus *Ephippiger—E. ephippiger, E. bitterensis,* and *E. terrestris*—gnaw the foliage and the green or ripe grapes in the Mediterranean vineyards. The damage, although episodic, can be important (122). Among the acridians, *Locusta migratoria, Schistocerca peregrina,* and *Dociostaurus maroccanus* have gregarious bands that are particularly destructive. *Miogryllus convolutus* has recently been recorded as damaging vines in South America (113).

Some polyphagous Coleoptera, in particular the scarabs, can sometimes destroy the green parts of the vine. In the eastern United States the rose chafer, *Macrodactylus subspinosus,* and the Japanese beetle *Popilia japonica,* whose larvae also attack the roots (123), are found. In France there are the green vine chafer, which includes in reality a complex of three related species—*Anomala vitis, A. dubia,* and *A. ausonia* (85)—which are found only in the vines on the sands of the Mediterranean coast and whose larvae only feed on decomposing plant material. Finally, practically everywhere in the world (156, 164, 195) the wasps (Vespidae) attack the ripe grapes, causing serious damage to table varieties.

Polyphagous Soil Insects

Mostly polyphagous soil insects are cockchafer grubs, larvae of various species: the common cockchafer, *Melolontha melolontha,* the pine chafer, *Polyphylla fullo,* and the hairy chafer, *Anoxia villosa* (85, 121). In Bulgaria (86) *Otiorrhynchus sulcatus* and *O. turca* larvae are recorded damaging the roots. Larvae of *Agriotes obscurus* cause damage in Romania (90).

CONCLUSION

In France, the major arthropod grape pests are the grape leaf rollers, *Lobesia botrana* and *Eupoecilia ambiguella,* and the tetranichids, *Eotetranychus carpini* and *Panonychus ulmi.* The two mite species were not pests until 1950 when the ill-considered use of organophosphates in controlling leaf rollers caused catastrophic outbreaks of mites. To avoid such outbreaks, studies were undertaken to promote the concept of integrated control in vineyards (1, 73, 148).

To control leaf rollers knowledgeably, levels of economic tolerance were established; these vary in relation to the phenologic stages of the vine, the climate, and the value of the crop. Population dynamics were based on data from traps, by using light, attractants, and sex pheromones, as well as from observing egg laying by adult moths. The hibernating forms of mites were carefully counted to predict future outbreaks.

French workers have shown that the use of certain pesticides causes mite outbreaks in two ways. First, pesticides destroy mites' natural predators, *Scolothrips* spp., *Orius vicinus* (Anthocoridae), *Stethorus punctillum* (Scimniini), and *Typhlodromus* spp. (147, 148). Additionally, certain insecticides and fungicides alter plant metabolism to produce conditions more favorable to mite growth and reproduction. In this way it has been shown that soluble nitrogen (amino acids) and reducing sugars play a large role in the nutrition and reproduction of mites (1, 56, 57). Outbreaks of leafhoppers (*Empoasca flavescens*
analogous process. For this reason, after detailed investigations, a list of pesticides and their effects on pests and auxiliaries was compiled (1). The problem of tetranychid outbreaks on grapes has also been studied in California (73). Ecological studies have made it possible to intensify the predation of *Metaseiulus occidentalis,* which attacks *Eotetranychus willamettei* (a minor pest) when *Tetranychus pacificus* is absent. As in France, pesticides that spare predators were selected.

To avoid the disadvantages of chemical control, recent experimental work has tested the effectiveness of *Bacillus thuringiensis* against larvae of *Lobesia botrana* (153). These are very susceptible but two difficulties are not yet resolved. The fact that eggs are laid and hatched successively over protracted periods and the behavior of the insect make contact between larvae and spores uncertain. Preventive treatment therefore cannot be based on defined infection thresholds.

Other projects, using entomophagous insects, have also been initiated. Two parasites of *Harrisina brillians,* the tachnid *Sturmia harrisinae,* and the hymenopteran *Apanteles harrisinae,* as well as a virus introduced from Arizona, were effective in lowering *H. brillians* populations in San Diego County, California.

Controlling the leafhopper *Erythroneura elegantula* by the mymarid *Anagrus epos* has been improved by providing refuges of *Rubus* sp. that harbor the nonpest species *Dikrella cruentata,* the eggs of which allow hibernation of the parasite. Other trials of entomophagous insects, e.g. against *Desmia funeralis,* are in progress.

There is no question that the continuing progress of ecological sciences will lead to a greater effectiveness of integrated control programs for grape pests as they have for other crops.

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